

cinefex

number 90
\$9.50
Canada - \$14.00



RESTORATION
IN PROGRESS
THIS ISSUE IS AWAITING ADDITIONAL CONTENT

PUBLISHER
Don Shay

EDITOR
Jody Duncan

ASSOCIATE EDITORS
Estelle Shay
Joe Fordham

DESIGN CONSULTANT
Michael Gross

ADVERTISING DIRECTOR
Bill Lindsay

ADVERTISING REPRESENTATIVES
Janice Hubbard Lindsay
Bernice Briggs
Michele Jeffers

CIRCULATION MANAGER
Margie Duncan

CIRCULATION ASSOCIATE
Samantha Lane

WEBMASTER
Gregg Shay

PRINTED IN USA
CINEFEX 90 - JULY 2002
CINEFEX is published quarterly at P.O. Box 20027, Riverside, CA
92516. Tel: 959-781-1917. Fax: 959-788-1793. URL: www.cinefex.com.
E-mail: letters@cinefex.com / editorial@cinefex.com / advertising@
cinefex.com / circulation@cinefex.com / website@cinefex.com. Printed
by Valley Printers, Riverside, CA. Copyright © 2002 by Don Shay. All
rights reserved. Reproduction in whole or in part in print or on the
Internet, without written permission is prohibited.

90



14 **Spider-Man**
Spin City
Joe Fordham

60 **Star Wars Episode II:
Attack of the Clones**
Love and War
Jody Duncan

article by Joe Fordham

When *Amazing Fantasy* #15 hit newsstands in August 1962, it bore a cover price of twelve cents. Today, the comic trader's bible, *The Overstreet Comic Book Price Guide*, conservatively values a mint-condition copy of it at \$27,500. What distinguished the slim volume — written by Stan Lee, drawn by Steve Ditko, with cover art by Jack Kirby — was a cover story introducing timid teen Peter Parker as a masked avenger who, bitten by a radioactive spider, used his suddenly acquired arachnid traits to fight crime as *Spider-Man*.

Parker's spidery characteristics — his now-familiar 'spider-sense,' his super-human strength and his ability to crawl up walls — were initially a hard sell for Lee. Marvel Comics publisher Martin Goodman, who feared younger readers would be nonplussed by the laconic hero clad in red and blue and repulsed by his spider origins, assigned the character to the last issue of what at the time was one of Marvel's less successful publications. After unexpected acclaim, *Amazing Fantasy* mutated into *The Amazing Spider-Man*, and rose to become one of the most enduring titles in the Marvel pantheon.

Dozens of like-minded crime-fighters have since crossed paths with Spidey — including the *Fantastic Four*, *Submariner*, *Daredevil*, *Thor*, *Hulk*, *Captain America*, even *Howard the Duck*. All were cast in the Marvel mold, as the mortal offspring of technology-gone-wild, in contrast to their more godlike D.C. Comics cousins, *Superman*, *Batman* and *Wonder Woman*. Spidey foes included characters similarly transformed by atomic age mutation — *Electro*, *Lizard*, *Rhino*, *Scorpion*, *Sandman* and *Venom*.

After more than three thousand comic book adventures, the wall-crawler prevailed, and his latest incarnation, *Ultimate Spider-Man* — somewhat sleeker and more toned, but still sporting red and blue — is now available online. Myriad merchandising spin-offs, an animated television series and, more recently, a large-format, digitally animated, 3D motion-base ride at Universal Studios Florida have also fueled *Spider-Man*'s popularity. A live-action film seemed inevitable, yet a CBS television series with brave but limited physical effects and zero superfoes — released theatrically outside the United States in 1978 — disappointed fans.

Cannon Films mounted the first attempt at a full-fledged *Spider-Man* feature in 1985, from a treatment by Leslie Stevens, co-creator of *The Outer Limits* television series, and a screenplay by Ted Newsom and John Brancato. As the screenplay evolved, production designer Mentor Huebner produced storyboards and large-format charcoal renderings of *Spider-Man* in action. Canadian visual effects supervisor Robert Ryan consulted with stop-motion animator Steven Archer, assistant to Ray Harryhausen in England, to determine the feasibility of animating *Spider-Man*'s nemesis Doctor Octopus, the radioactive spider that bit Peter Parker, and long shots of *Spider-Man* swinging through New York.

When Cannon co-founders Menachem Golem and Yoram Globus dissolved their partnership in 1989, Golem continued to pursue development himself, then sold the rights to Carolco Pictures in 1991. Carolco brought with it the attentions of director James Cameron. Cameron's involvement piqued the interest of the comic fan community, particularly after his detailed 'scriptment' — a screenplay/treatment hybrid — appeared online in 1996, imbuing the web-slinger with genetically-mutated wrist spinnerets and pitting him against three of his comic book adversaries, Electro, Sandman and Ock. When complex litigation over the ownership of rights stalled progress, Cameron eventually withdrew from the project; and, in March 1999, Columbia Pictures and Marvel Enterprises issued a public statement that they were picking up the torch. Columbia brought in screen-writer David Koepp; and, nine months later, director Sam Raimi emerged as the winning candidate to direct, with John Dykstra supervising visual effects, and digital production based at Sony Pictures Imageworks in Culver City.

To discuss the possibilities for Spidey screen ingredients, Dykstra first met with Raimi in Georgia, where the director was shooting *The Gift*. "The screenplay was still a work-in-progress," Dykstra recalled, "so we were in a conceptualization stage, trying to figure out the physical components of the character that were necessary to tell the story. We were telling the origin story, so we knew a very large component of our film would be based on defining who Peter Parker was before he became *Spider-Man*. There was a huge amount of work trying to figure out the best way to handle that." Dykstra and Raimi also addressed narrative issues that had become complicated by the character's rich comic history. "One of the problems was that we had a surfeit of villains. We ended up winnowing characters down in order to clarify the story." The plot ultimately ejected Doctor Octopus and other villains in favor of a single adversary, the Green Goblin — the green-skinned gargoyle alter ego of embittered chemical engineer Norman Osborn, who first appeared July 1964, in *The Amazing Spider-Man* #14.

As the film's narrative took shape, Raimi and production designer Neil Spisak held roundtable discussions with Dykstra, Imageworks producer Lydia Bottegoni and Imageworks visual effects co-supervisors Scott Stokdyk and Karen Goulekas, physical effects supervisor John Frazier and stunt coordinator Jeff Habberstad. "We tried to do as much as possible live," asserted Dykstra. "The mechanical effects guys were asked to press the limits of their capabilities, and the stunt guys were asked to press the limits of their capabilities, to make this character practical in terms of time and money. The film was very much an alloy in process, where many ideas were hammered together and all the fissures and differences in tone became a part of the strengths in storytelling. Sam allowed us to become collaborators, and because of that we all became invested in the picture."

Spisak led the design process with a team of conceptual artists — including Bernie Wrightson, Miles Teves, Warren Manser and James Carson — who developed designs and storyboards with Raimi to set the cinematic tone. "We had a strange problem," Raimi commented. "For myself, and I assume for other readers of *Spider-Man*, the great strength of the character was that Peter Parker was one of us. He was a regular kid, from a lower middle-class family, and he was not part of the 'popular' crowd at school. Most kids who read comic books were, like Peter, kind of geeks. So, first, they identified with him, *then* he became a superhero. In the movie, this meant we had to create a reality for Peter for his transformation to affect us. We couldn't set it in a super-stylized comic book world. However, we also knew that if we tried to drop characters as flamboyant as *Spider-Man* and the

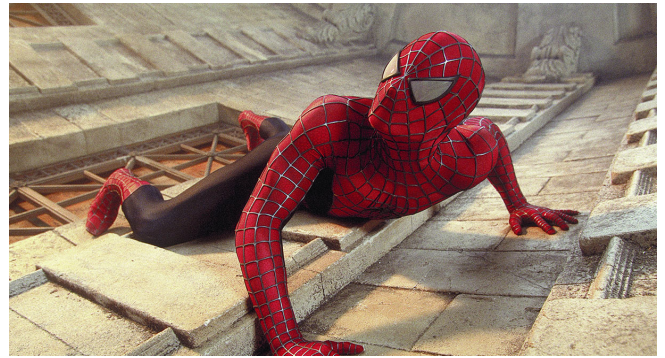
Green Goblin into real-world locations in New York City, it wouldn't hold them. So we had to come up with a style that was real, yet had the slightest exaggeration — so audiences could still identify with the characters, and yet believe *Spider-Man* could actually swing through that world."

Raimi's familiarity with the comic, and his commitment to closely observe its design aesthetic, also influenced his approach to the creation of *Spider-Man*'s costume, a duty entrusted to costume designer James Acheson. "I didn't feel it was my job to make a new look for *Spider-Man*," Raimi noted. "Upon every incarnation of artists' conceptions of *Spider-Man* looks, I asked myself: 'Why are we changing this?' The original was something I'd loved so much, and others had loved so much, that I felt it would be best to be faithful to it and, with the help of James Acheson, update it."

Acheson set up operations in Burbank with a team that included wardrobe specialist John David Ridge and longtime collaborator Raymond Scott, who led sculptural duties for the *Spider-Man* suit. At producer Ian Bryce's invitation, Acheson also joined forces with Tom Woodruff, Jr. and Alec Gillis — founders of Amalgamated Dynamics Incorporated — to brainstorm a technical and creative approach to generating the movie's requisite twenty-eight *Spider-Man* suits.

Early on, the team grappled with a challenge inherent in a story in which its lead characters were masked — how to make audiences connect with characters whose faces would be unseen throughout much of the movie. "Sam made a funny point in one meeting," related Gillis. "He held up a rendering of *Spider-Man*, and one of the Green Goblin, and puppeteered them, doing the voices: 'So, *Spider-Man*, you think you can destroy me?' 'I'm sure going to try!' It was like the old cartoon *Clutch Cargo*, with no emotion or expression — and that was a problem. If you think of superhero movies like *Batman* or *Robo-Cop*, they all reveal part of the eyes or mouth to help convey emotion. This was a huge risk." Raimi eventually decided to portray *Spider-Man* unmasked as often as the story allowed.

Acheson tailored most versions of the *Spider-Man* suit as one-piece spandex unitards with hood, gloves and boots integral, which kept the material skintight. The effect was enhanced by a painted texture that emphasized Peter Parker's transformed physique. Referencing Warren Manser concept art, Acheson worked with Martin Izquierdo Studio, silkscreen specialists in New York, to airbrush muscle patterns onto a white unitard stretched over a full-body lifecast of actor Tobey Maguire, who had



Forty years after *Spider-Man*'s Marvel Comics debut — and seventeen years after the property first went into film development — director Sam Raimi finally brought the popular crimefighter to the big screen. With coordinated input from visual effects supervisor John Dykstra and physical effects supervisor John Frazier, Raimi realized *Spider-Man*'s arachnid capabilities — web-slinging, wall-crawling, superhuman strength and spider-sense — through live, mechanical means whenever possible. Leaps into a more fantastic realm were achieved by the digital effects crew at Sony Pictures Imageworks.



The life of high school misfit Peter Parker (Tobey Maguire) is forever transformed when, during a trip to a science museum, he is bitten by a genetically engineered 'super-

been cast as the film's title character. Acheson's team then opened up the spandex, pinned it out like an animal pelt and photographed the material with a large-format still camera. Imageworks artists Yakov Baytler and Marzette Bonar digitally generated a grid of tiny rectangles from this image, squashing and stretching rectangles to define muscle shading, and created muscle and color maps. Izquierdo then broke the design into 120 separate silkscreen patterns and applied the textures to the spandex.

spider.' During the live-action shoot, entomologist and bug wrangler Steven Kutcher coaxed some on-cue behavior from real spiders, painted with red and blue markings to make them resemble the arachnid emblem on Spider-Man's costume. For closeups of the spider biting Parker, Imageworks digitally modeled the mutant spider from still photographs of the live version, then animated it to pierce Parker's flesh, tracking it to a super-macro closeup of Maguire's hand.

Ray Scott sculpted a stylized muscle suit for Maguire to wear under the spandex suit, and a streamlined understructure that would fit around his head. Foam muscle sections — molded and cast by ADI — were sewn into the undersuit. ADI also cast a rigid vacuform headpiece, which covered Maguire's skull and face, cutting out around his eyes and ending in a line above his upper lip. A second rigid section fitted around the actor's lower jaw. Joined with flexible foam rubber, fitted snugly around Maguire's mouth, the head-hugging contraption solved a technical problem that arose from the actor's breathing through the spandex. "The foam rubber not only made everything fit together," said Woodruff, "it also kept Tobey's breath from fogging his lenses. That was a big problem until we extended the foam rubber up around the eyes, letting it act as a gasket."

Spider-Man's trademark buglike lenses also went through a range of designs, materials and colors. Acheson experimented with white mesh and mirrored lenses, but ultimately developed a lens with Oakley, the sunglasses manufacturer, which coated plastic lenses with iridium, creating a semi-reflective finish that took on different colors, depending on lighting conditions. ADI made rigid frames to hold the lenses in place with magnets and clips. The frames blended into a raised spider web design that covered the red portions of the suit.

To create a symmetrical webbed grid on the suit, Acheson sketched a web design, which ADI mechanical supervisor David Penikas scanned and translated into CAD plans. A CNC milling shop used the CAD data to mill precise spider web forms in aluminum. ADI mold shop supervisor Steve Frakes oversaw molding of the intricate metal forms, while lead foam technician Mark Viniello supervised production of more than sixty full-body patterns. After ADI soaked the webbing in black dye, the wardrobe team airbrushed a subtle metallic sheen onto the leading edge of each web. "We had the easy part," commented Gillis. "Jim Acheson's team had to figure out not only where the webbing should go on the body, but how much it would shrink. It seemed like an impossible task, because it had to be fitted under tension. But they drew it out on a guy, took it off, opened it up, then hand-glued it to the spandex. When I saw the completed suit, I was blown away by how clean it was. Everybody asks us: 'Is that CGI? Has it been touched up?' It was just that seamless!"

The suit for *Spider-Man*'s adversary, the Green Goblin, required an equally intensive preproduction development. "We had to back into that one," commented Sam Raimi. "In the comic, Stan Lee gave Peter Parker a great reason to make his costume — he enters a wrestling contest to win some money, and he designs this outrageous costume to compete as *Spider-Man*. But, with Green Goblin, there was no justification for his outfit, which is a scaly, green, skintight leotard, with some sort of a frock over it, and what looks like a latex mask. It was difficult to justify why he would create that costume for himself."

An early animatronic prosthetic makeup by ADI was a literal interpretation of the comic, sculpted on a lifecast of Tom Woodruff, then cast out of plasticized silicone. Woodruff wore the makeup and performed a film test demonstrating a range of mechanically enhanced expressions. "I was in love with the idea of an animatronic makeup," Woodruff admitted. "It was a very gothic, gargoyle-esque Green Goblin, but very much like the comic book character. When we first mentioned it to Sam, he was doubtful we could pull off an animatronic that would be believable without being over the top. But we went for a pretty subtle range of movement; and when Sam saw the test, he said: 'You did it! You totally convinced me. However, I can't get around the idea that this guy could pull out a rubber mask and still have this much mobility.'"

Raimi instead elected to give Green Goblin a rigid, protective mask, explained by an invented backstory in which Norman Osborn was a collector of masks. Sculptors Jim Kagel and Gregory Smith produced a series of new designs for the mask at ADI, while Martin Smeaton sculpted a complementing body armor suit at Acheson's workshop. The action-packed nature of the story mandated extreme flexibility in the suit, as emphasized by Goblin actor Willem Dafoe in his first costume fitting. "Willem did the splits in the fitting room," remarked James Acheson, "and said, 'I want it to be that flexible.' So it ended up being an all-in-one suit, with all of the pieces attached."

The main body of the Goblin costume was a pearlescent green undersuit fabricated by John David Ridge using spandex covered by an elasticized vinyl. Martin Smeaton sculpted sections of body armor to fit a lifecast of stunt performer Chris Daniels, prior to Dafoe's casting, then ADI molded and cast the pieces in fiberglass. Eric Hayden devised an armor paint scheme using a spectrum-shifting car paint that displayed chromatic range from green to purple, with the same pearlized quality as the undersuit. Brent Baker molded and finished the helmet, which was cast out of thin fiberglass and fitted with gold iridescent, iridium-coated Oakley lenses. "The helmet had lights inside the eyes and mouth that were adjustable," said Gillis, "so if Sam wanted to see in, we could fade them up and the camera could see Willem." Acheson also commissioned ADI to create a



Initially falling ill, but recovering quickly with improved vision and newly buffed physique, Parker begins to discover bizarre physical manifestations of the spider bite, such as the ability to shoot webbing from his wrists. Raimi's decision to update the character with organic web-spinners — as opposed to the mechanical bracelets Parker sports in the comic — spurred controversy among Spider-Man enthusiasts. The physical effects crew supplied a super-stretchy urethane to represent a range of practical webs on the set, but all web-shooting effects were generated digitally at Imageworks.

lighting system that depicted a flowing energy effect, emphasizing the advanced technology powering the suit. After lengthy research and development of a laser light backpack, the decision was made to scrap the suit lights, retaining just the helmet illumination.

Acheson and ADI created twelve Goblin suits, ultimately shaving the fitting times to just thirty minutes, similar to the fitting time for the *Spider-Man* suit. ADI technicians Shownee Smith and Seth Hays accompanied Acheson's wardrobe team on set, prepping and operating the Goblin helmet and chaperoning the daily maintenance of armor.

Concurrent with the creation of the physical superhero suits, the Sony Imageworks team was also at work constructing digital facsimiles of the characters to transport them into realms beyond physical capabilities, as suggested by the director's shooting plan. "I wanted to present all of Peter Parker's human interaction in a very personal, intimate way," stated Raimi, "so most of the time I did not want to make the audience aware of the use of the camera technique, to draw them into the characters. I then applied a second stylistic approach, with the help of my great team of storyboard artists and animators. Once Peter became *Spider-Man*, moving in a way that none of us could move, I wanted to capture the brilliance and the beauty of this ballet, fifty stories above Manhattan, but I didn't want to present this with a cut. I wanted to identify with the human being, then blossom into the hero with him. So when he was the hero, we could soar with him in very long, uncut takes where we felt that we were *Spider-Man*, swinging with him on these tremendous arcs high above the streets."

To investigate how far live performance could take the high-flying action scenes, John Dykstra and Imageworks animation director Anthony LaMolinara enlisted the assistance of Christopher Childers, a dance coach for Cirque du Soleil, who performed acrobatics wearing motion capture sensors. "Christopher was very talented," said LaMolinara. "We had him swinging on rings, from one to another; but no matter how wonderfully he moved, the grace and strength required to swing at a hundred miles per hour between two buildings was superhuman. There was no way a human being could do that, no matter how strong he was."

While the motion-captured footage served as visual reference, Dykstra and LaMolinara relied instead on key-frame animation to realize the principal digital performances in *Spider-Man*. "Motion capture is great," commented Dykstra. "We used it in the film for animating background crowds, doing things that people do. When you start making characters do things that real people cannot, that requires a whole new range of motion. If you start animating those kinds of scenes with motion capture, you end up going back and modifying a performance so much that you lose the one



Parker first learns of his organic web-shooters – subtle spinneret appliances built by Amalgamated Dynamics Incorporated – during lunch in the high school cafeteria, when a strand of sticky material accidentally shoots from his wrist and snares a lunch tray across the room. Though the web-shooting effect was digital, the physical effects crew supplied subsequent practical webbing and interaction of the lunch tray wobbling upon impact. Sam Raimi wields the tray on set.

thing that motion capture gives you — which is high frequency, personality detail. CG animation is more like traditional cel animation in that it captures a global representation really well, but it lacks ‘noise.’ It lacks the glitches, ticks and subtle postures, like if a character has a sore hip, or a bad thumb, or a hinky ear. When our characters were at speed, performing to their superhero or supervillain paradigms, the animators painted all that in. They didn’t need that motion-captured detail.”

To guide the animated *Spider-Man*’s performance, Raimi and his associate producer Grant Curtis sifted through hundreds of *Spider-Man* comic books, selecting poses that best represented their hero’s look and movement. Printed out as an array of 72 color frames, the chosen illustrations displayed a dynamic range of movement. “Sam made it very clear that we had to push the limits of what a real human could do,” Scott Stokdyk stated. “He selected frames where *Spider-Man* made a very low profile — knees tucked up, arms down between. There were a lot of classic swinging poses where *Spider-Man* arched his back with one arm extended and used his body for momentum as he swung around curves.”

Digital artist Koji Morihiko led construction of the CG *Spider-Man*, drawing on lessons learned from Imageworks’ prior experience with the digital reconstruction of human anatomy. “*Hollow Man* helped us understand the limits of rotation for the human skeleton,” Stokdyk stated. “We knew what the range of motion was, medically, and where the muscles connected; and we knew where to push that when *Spider-Man* went into an extreme pose.” After studying videotape of Chris Daniels — Tobey Maguire’s stunt double — performing ranges of motion and observing how his muscles flexed, Morihiko decided to ‘physique’ the CG *Spider-Man* model using traditional surface modeling methods, rather than building a complex underlying muscle simulation system. “We needed super-tight control to fine-tune *Spider-Man*’s performance, hand-moving the model in a very artistic way, giving it different rotations. That really helped us emulate the comic poses; so wherever we saw that *Spider-Man* needed to bend his waist a little more, or move a shoulder back more, animators could sculpt that into place.”

The dynamic between Imageworks’ physiquing and animation departments also played its part in establishing digital character tolerances. “As an animation director, I’m ready to push the character as far as it can be pushed,” asserted LaMolinara. “Sometimes that means ‘breaking’ the character. Physiquers like to put limits on, and we like to turn them off! If we moved a shoulder too far, for instance, Scott might come back and point out that two surfaces of the model were intersecting in an unnatural way; but the animators and I always wanted the pose to ‘sing,’ to shine, and you can’t always achieve that without intersecting volumes that don’t push together that way in real life. When we had to let the model intersect itself, that created problems with rendering or lighting, but most often we sneaked it through!”



Tracking between source points on Maguire’s wrists and target objects, Imageworks animators determined web trajectories, then procedurally propelled virtual jets of particles from the spinnerets, dialing in appropriate physical attributes such as opacity and thickness. The web simulation was designed to produce a viscous liquid spurting forth from Parker’s wrists, which would then solidify as it made contact with its target. Multiple rendering passes created specular highlights and rainbow effects in the translucent webbing, while a refractive

quality – which distorted the background behind it – was added in compositing.

To ensure perfect seams in the model, digital artist Daniel Kramer generated textures as a subdivision surface, an algorithmic technique that creates

streamlined shapes as refined 3D polyhedral meshes. Shader artist Sing-Choong Foo incorporated the digital *trompe l’oeil* design that James Acheson’s team silk-screened to the practical suit, mapping this to the subdivision surface, and created raised web textures as a RenderMan line primitive, procedurally generating the complex geometry at render time.

For construction of the digital Green Goblin, lead CG modeler Edward Taylor used a Gentle Giant Studios cyberscan of the Goblin suit mostly as a guide. “We had to model the Goblin virtually from scratch because it was made up of so many individual pieces,” noted Stokdyk. “In real life, the Goblin was covered in armor plates, but these still had some flex to them. When the real Goblin lifted up his arm, for example, the epaulette on top of his shoulder would sometimes pop off. We had to avoid that, so Alberto Menache wrote a muscle and surfacing system that simulated a combination of hard surfaces riding on top of softer surfaces. This allowed us to control how the pieces moved relative to the surface, how they moved independently, and how much they flexed and folded into each other.” Peter Nofz physiqued the CG Goblin, while J.J. Blumenkranz set up animation controls, and Sing-Choong Foo developed a lustrous surface shader that matched textures of the live Goblin costume. “The Goblin lighting model and shader were pretty complex, so it helped immensely that our model was so detailed. We could control the shading on each separate surface, applying a classic anisotropic effect, so the colors changed hues from different angles in terms of their brightness and luminosity.”

While work on the characters continued, the filmmakers also addressed the challenge of setting the film in the gritty, teeming reality of New York City. Neil Spisak set about designing an extensive location shoot in the Big Apple itself, interwoven with sets built in Los Angeles, while John Dykstra developed a strategy of his own. “We would have liked to shoot the whole movie in New York,” Dykstra remarked, “but given the constraints of the city — even prior to the terrorist attacks of September eleventh — it was just not possible. We couldn’t shut down busy areas and fly our camera in amongst the high rises. So we decided to shoot all backgrounds as separate elements, bring them together and rebuild our own version of the city digitally, both at night and day. It was probably one of the most difficult things, and, hopefully, one of the least recognizable things visual effects provided for the film.” The digital city also allowed Dykstra to articulate Raimi’s energetic camera style. “The concept was to cover *Spider-Man* in the same way you see skydivers who compete in international competitions, where both the skydiver and a cameraman are airborne. So we thought of it as if *Spider-Man* always had his own cameraman, who travels with him and is as capable and as agile as *Spider-Man* — perhaps in his own way more so, because he has to aim a camera while he’s in motion. That was the conceit: we were a stunt photographer swinging with *Spider-Man* through the city.”

Scott Stokdyk delegated construction of digital Manhattan to a team of Imageworks CG supervisors — Sam Richards initiating building development, before handing duties to Ken Hahn, who delegated to building team leader Francisco DeJesus. Karen Goulekas set up an infrastructure for visual effects shot production, sharing duties with Stokdyk for the early part of the production, and

joined Dykstra and Spisak for location scouts in New York. While touring the city, Spisak selected a mix of modern and more traditional high-rise structures, photographing and numbering a selection of fifty buildings. Raimi, Spisak and Dykstra chose fifteen ‘hero’ structures to be featured in closeup, with twenty midground buildings and twelve background buildings to be built at successively lower levels of detail. The 3D buildings were based on photographic studies. “We sent a team to New York for several weeks,” Stokdyk recalled. “Our lead texture artist, Kerry Nordquist, took about 8000 photos using Kodak 5974. Kerry photographed the buildings with overcast skies whenever possible to create a neutral lighting. Because we were going to be using the same textures for both day and night scenes, they had to support a wide dynamic range. We later scanned the negative at Imageworks, so it went through all the same color correction cycles as the effects plates from the shoot.”

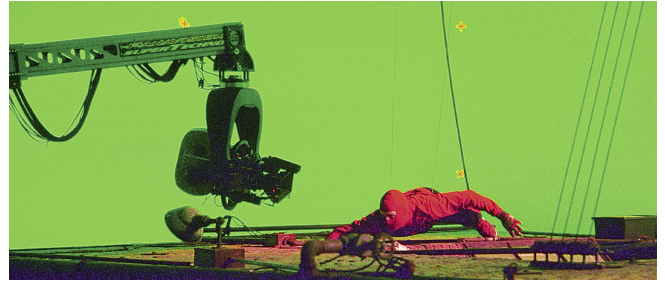
To prepare for the 3D modeling of the city, architectural modeler Alex Whang first examined architectural plans of actual New York buildings; but when these provided inadequate detail, he joined Nordquist in New York to create his own laser surveys of buildings. Using a surveyor’s tachymeter, Whang measured elevations by triangulating laser points and collected 3D data of all the selected buildings. Back at Imageworks, Nordquist, Apryl Knobbe and Federico Rivia led a ten-person texture team that unwarped lens distortion from the building photos, seamed together mosaics of, on average, ten photos per façade for closeup buildings, and evened out variations in hue and tone. Modelers used the tiled image and the survey data to create 3D buildings in Alias Wavefront’s Maya, then passed the models back to the texture painters, who applied textures in *Side Effects’* Houdini. “Texture painting was much more complex than we imagined it would be,” said Stokdyk, “and we had imagined that it would be pretty hard! Our texture painters bore the brunt of the work because they had a finger in almost every technique we used, and they became swamped with the complexity. We were texture-painting for almost two years.”

Nordquist led a team of ten texture artists who used a combination of techniques to surface the buildings, mapping digitally projected photographic textures onto the 3D models, as if from a slide projector. Displacement mapping created rough surfaces by distorting geometry during rendering, and bump mapping created the impression of rough surfaces through shading. “Most of the hero buildings required custom painting,” Stokdyk noted. “Projection tended to stretch textures over ledges and raised areas. It was very tricky deciding where to use projection, displacement maps or bump maps each time.”

To create the effect of light bouncing between the surfaces of the CG buildings, Sam Richards investigated global illumination radiosity techniques — an algorithmic process that calculates reflectivity of surfaces — and ultimately adopted another hybrid approach. “We converted our geometry to Discreet’s Lightscape environment, rendered out a radiosity pass and brought that back to our composite,” said Stokdyk. “It turned out this didn’t give us the fine control we needed, because so much of our geometry was created using displacement maps that didn’t fit into this pipeline. We ended up doing a lot of texture painting to get the final radiosity look, in a lot of cases ‘un-baking’ the radiosity pass and painting in those textures to give us more control.”

Windows were also daunting for the modeling and texture-painting teams — a single hero building such as the Equitable Center, a soaring fifty-story midtown edifice, contained more than 6500 glazed panes. “For super-close buildings, windows became a pure modeling job,” observed Stokdyk. “Modern and mid-range buildings involved rotoscoping; and for far-distant buildings, the windows became a photographic or painted texture. For our older, classical-style buildings, where there was a lot of visible stone, we had to replace all the windows to create reflections and specular hits in the window glass. At nighttime, the buildings were really brought to life by their lit interiors.” To add depth to window interiors, Nordquist devoted part of the New York photo shoot to the photography of office interiors, from which Imageworks generated 3D glimpses of high-rise occupancy. “We used a very wide-angle camera lens, stood against one wall, and took a picture of the room as a distorted fisheye photo. We then digitally unwrapped the distortion and projected that texture inside a virtual cube, so we could pan around; and as the camera flew by outside we’d see a virtual perspective shift inside the room. It was similar to the virtual camera fly-throughs you see on real estate websites. We built a couple of interiors with 3D furnishings for extreme closeups, but the 3D cubes were a very handy procedural alternative to building geometry inside all those thousands of windows.”

The layout of the digital city proved no less a challenge. Dykstra and Stokdyk first examined commercially available 3D models of Manhattan to help choreograph action, but ultimately relied on city maps and continuing discussions with Raimi to structure the shots. Storyboards gave way to a year of 3D previsualization, during which animation tests led to a realization that the architecture of New York dictated its own rules. “When we first started placing buildings,” commented Stokdyk, “we set them up as modular pieces to use as a 3D construction set. But when we tried that, Alex Whang, our modeler — who has an architectural background — found there was a very specific feel to the way the city blocks of New York were laid out. Human engineering and a historical perspective have dictated where architects can build. For example, you might find a couple of classic old-style buildings next to each other. If somebody wanted to build a more modern building next to those, they would have to respect zoning laws, distances and height variances. So we not only had to take into account the shot composition, the animation of *Spider-Man*, and how he interacted with the buildings, we also had to be mindful of all these other architectural considerations. It was impossible to work out a modeling system that could procedurally take those criteria into account. It was also difficult to take a collection of buildings and make them look like a city block using cut-and-paste techniques.”



In a makeshift costume he has donned for a wrestling competition, Parker chases a robber who has slain his uncle, taking advantage of an earlier discovery that he can now climb sheer walls due to barbed protuberances growing out of his fingertips. Frazier and his team devised a number of wall-crawling rigs to assist Tobey Maguire and his stunt doubles in performing the superhuman feat. The basic setup consisted of a horizontally-oriented wall set dressed with pipes and electrical conduit, over which, suspended from the stage ceiling, was a platform that rode on air bearings. Cables connecting Maguire or his double to the platform – allowing them to ‘climb’ convincingly – were painted out digitally.

Distant city views were built by digitally tiling photographic plates of the Manhattan skyline and projecting textures onto a curved surface, which backed the city model like a giant digital cyclorama. Skies were mostly painted, but were sometimes stitched from nodal tiles and projected into the 3D dome. Lighting of the background plates often helped ground lighting through the CG city, as sunlight bounced between varieties of texture — glass, steel, sandstone, granite, marble, concrete. “There was so much complexity in each shot,” Stokdyk. said. “We had light falloffs, hue variations and adjustments in saturation, contrast, sharpness. With every CG building, we had to make those decisions dozens and dozens of times.”

To blend the multitude of elements, Stokdyk’s team developed a multilayered rendering approach. “We did several tests with different renderers to find the best true motion-blurred reflections,” Stokdyk explained. “Mental Ray worked really well for us, so we ended up building a pipeline where we exported all of our geometry and textures to Mental Ray, rendered the motion-blurred reflections, then put them back during the composite. This meant we had to include all of our CG buildings with textures in that render, with all of our background tiles. Laurence Treweek set up the method to handle a huge reflection render that contained our entire virtual environment.”

With the digital city taking shape, and animation tests proceeding, the stage was set for the principal photography of *Spider-Man* to begin at Sony Pictures Studios on January 8, 2001.

Peter Parker’s fateful encounter with a spider — updated in the film to a genetically engineered mutant — included the first practical and digital effects in the film, seen as Parker and his classmates visit an exotic spider exhibit within a science museum. Entomological consultant Steven Kutcher, veteran of *Arachnophobia* and more than 200 film and television productions, supplied practical spider effects at the invitation of property master Robin



Continuing the chase, Parker pauses atop a cupola before slinging webs and vaulting rooftops. The shot was entirely CG, save for the area around the character’s eyes. Tracking markers applied to Tobey Maguire’s face facilitated replication of live-action camera moves on his digital body double and surrounding virtual environment.



Sony Imageworks computer generated cityscapes to augment a limited New York location shoot and stage sets built by production designer Neil Spisak. Scouring Manhattan, the filmmakers chose fifteen hero structures, twenty midground buildings and twelve background buildings, modeled at successively lower levels of detail. Some eight thousand photographs of the city served as textures for the 3D skyscraper geometry.

Miller. “I am a professional entomologist with a master’s degree in insect behavior,” said Kutcher. “In the movie industry, I’m commonly known as a ‘bug wrangler,’ although probably the correct term is ‘arthropodologist’ — somebody who works with jointed-legged animals that have an outside skeleton.” Early in production, Kutcher presented a selection of arachnids to Raimi and the producers, who were seeking a spider resembling the arachnid emblem on the newly designed *Spider-Man* costume. “The design was similar to a black widow, but with a teardrop-shaped abdomen, and they wanted it to be blue and red and black, like *Spider-Man*’s costume. I recommended a spider called *Steatoda*, which was from the black widow family, *Theridiidae*. It was brownish in color, but it would not present the danger of potential envenomation. I suggested we could use this as a model and attach a prosthesis, which I had done successfully to a live spider on *James and the Giant Peach*.”

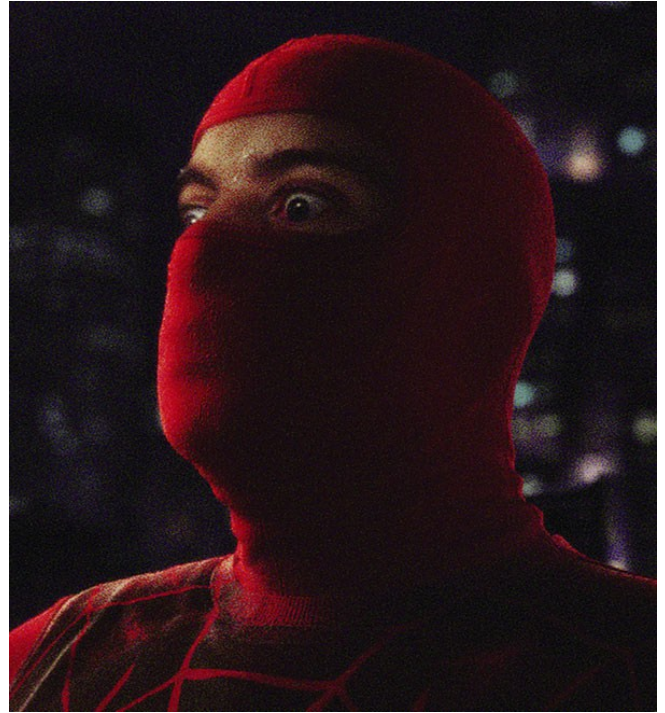


A wire-frame mask and hood were tracked to the live-action shot of Maguire, then replaced with CG cloth produced through Imageworks’ cloth simulation technology. As Parker gains a view of the killer’s car below, the camera rotates and match-moves from the closeup of Maguire to a shot of the all-CG Spider-Man, which performed the character’s balletic moves through Manhattan’s concrete canyons. Raimi and his storyboard team sifted through hundreds of *Spider-Man* comic books to select classic poses that best represented the character’s established swinging style.

Among the nearly 200 spiders supplied for the laboratory scene were breeds chosen to represent a range of arachnid abilities genetically distilled into the mutant that bites Peter Parker. Kutcher nominated Delena Cancerides, imported from New Zealand, to play a jumping spider, Kukulcamia to portray a funnel web spinner, and Agelenidae to demonstrate enhanced danger awareness, or 'spider-sense' — a feat achieved by gently blowing at Agelenidae through an off-camera drinking straw. Steatoda played the mutant, being small enough to perform the crucial webbing down, descending unobtrusively onto Peter Parker's hand.

To transform Steatoda into the mutant, Kutcher collaborated with Neil Spisak's art department to fabricate a tiny, lightweight latex spider costume, detailed with red and blue markings. The prosthesis, fitted over the Thorax of a Steatoda, was open at the bottom to allow the spider to breathe. When Kutcher discovered that the prosthesis inhibited the Steatoda's spinnerets located in the rear of its abdomen, he devised a backup plan, painting the red and blue design directly on the spider's thorax. "We didn't apply the makeup very permanently," remarked Kutcher. "In fact, we found that if we applied the decal and Steatoda wasn't fed its diet of flies, it lost weight and the makeup would pop off. So one of our problems was keeping a spider the same size."

Drawing on his familiarity with insect behavior, Kutcher developed a system to coax Steatoda to web on cue by balancing the spider on a paintbrush, then tipping it off, causing it to release a safety web to arrest its fall. Assistant Michelle Pollack rehearsed the Steatodae on set, limiting her tests so as not to exhaust the insects' web supply, then handed Kutcher the most successful candidates, keeping backups in reserve. Raimi captured the descent in-camera, the live spider landing on Maguire's hand, with a foreshadowing glint of red and blue. To enhance the drama of the bite, Imageworks digitally modeled the mutant spider from still photographs of the Steatoda, then animated the arachnid to pierce Peter Parker's flesh, tracking it to a super-macro closeup of Maguire's hand.



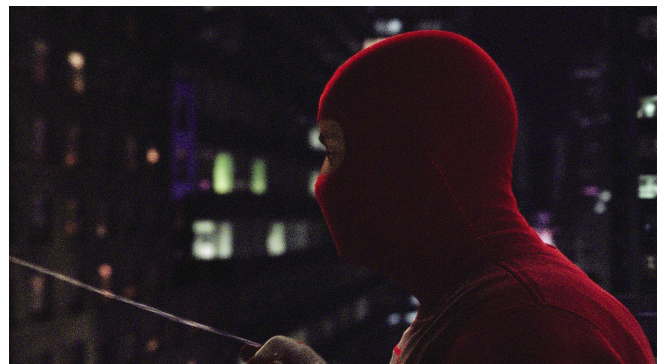
A wire-frame mask and hood were tracked to the live-action shot of Maguire, then replaced with CG cloth produced through Imageworks' cloth simulation technology. As Parker gains a view of the killer's car below, the camera rotates and match-moves from the closeup of Maguire to a shot of the all-CG Spider-Man, which performed the character's balletic moves through Manhattan's concrete canyons. Raimi and his storyboard team sifted through hundreds of Spider-Man comic books to select classic poses that best represented the character's established swinging style.

Affected by mutant spider toxins, Parker rushes home, prepares for bed and catches sight of his shirtless reflection in a mirror, looking gaunt and sickly. By the time shooting commenced, Maguire was anything but emaciated after rigorous physical training for the film, so Dykstra suggested utilizing motion control repeat passes to create the illusion. Imageworks motion control supervisor Nic Nicholson first photographed the scene using a Zebra motion control rig to pan up Maguire's body to his queasy face. Once Raimi was satisfied with the actor's performance, Dykstra stood a skinny body double in Maguire's place, played back the camera move with the double mimicking the performance, then shot a third pass of the empty background. Imageworks digital artists Marc Rienzo and Jeff Olm tracked the shots in Inferno, painted out the double's head against the empty plate, then rotoscoped, match-moved and composited Maguire's head to the skinny body at the jaw line.

The extent of the character's physical transformation became a hotly debated topic among comic fans when word of Spider-Man's alleged organic web-shooting appendages surfaced in 1996. For Raimi, the issue became a matter of practicality in the modern-day retelling of the legend. "I read James Cameron's ninety-page scriptment, which was very good," stated Raimi. "It updated the concept so that Peter Parker was bitten by a spider undergoing genetic transmutation, and some floating strands of DNA spliced themselves into Peter's genome. It seemed like a logical updating of modern science, in the same way that I'm sure a radioactive spider seemed logical when the comic book was originally written. So we kept that. The scriptment also had this idea that the mutation went one step further and allowed Peter to develop the ability to shoot spider web from his wrists. Although this was considered heresy by many of the Spider-Man true believers, I felt it was another logical updating of the story. We were already taking the leap that a man could take on spider abilities — climbing walls, having the proportionate strength of a spider, and spider-sense — so I felt, why not give him one more ability? In a way, it was not as big a leap as having this high school boy invent this fantastic fluid that could remain in



Parker shoots a web toward an apartment building, preparing to swing down to ground level and confront the fleeing criminal. CG building interiors and exteriors were fashioned separately to create accurate perspective shifts during virtual camera moves. Interiors consisted of hero 3D-modeled and textured settings for closeups, or 2D cheats, which were fish-eye-lens digital photos of real room interiors, unwarped and projected into faux cube environments to produce fake perspective shifts as the camera flew by. CG building exteriors were added to the final shots.



Parker shoots a web toward an apartment building, preparing to swing down to ground level and confront the fleeing criminal. CG building interiors and exteriors were fashioned separately to create accurate perspective shifts during virtual camera moves. Interiors consisted of hero 3D-modeled and textured settings for closeups, or 2D cheats, which were fish-eye-lens digital photos of real room interiors, unwarped and projected into faux cube environments to produce fake perspective shifts as the camera flew by. CG building exteriors were added to the final shots.

liquid form, shoot from mechanical devices, then be super strong. It was all about not losing identification with this average boy which, for me, was the real strength of the character.”

Producer Ian Bryce commissioned ADI to come up with experimental organic web shooters as a prosthetic test makeup. “We called them ‘wrist spinnerets,’” said Alec Gillis. “They looked as though they were growing out of Peter Parker’s arms. Sam was treading the ground between wanting to show the audience how *Spider-Man* exudes this fluid and not having it become grotesque, so we ended up creating a very subtle appliance. We sculpted a cluster of little bumps and cast these in foam as a thin prosthetic, the idea being that each bump was almost like a nipple, where the web fluid would come out of multiple points.”

In a homage to the original comic concept, the art department also designed, and the property department fabricated, mechanical web-shooter bracelets — with touch-sensitive triggers in the palm — that fit around Tobey Maguire’s wrists, their purpose to focus the web’s trajectory. Though the bracelets were only visible when Parker was in civilian clothes, testing the apparatus, Dykstra eventually streamlined the concept further, per Raimi’s directive, and commissioned Composite Image Systems in Hollywood — one of three subcontractors brought in as the visual effects shot count expanded — to digitally remove the props. “I am sure that there are people who are absolutely adamant that this picture should not be shown because we deviated from the original comic book concept of *Spider-Man* building his own mechanical web shooters,” said Dykstra. “It turned out to be a tempest in a teapot. We had to think about what it meant for our story — the whole concept of the character undergoing an organic, DNA-modified transformation made more sense. It also tied into all the issues of Peter going through adolescence, implied in parallel to the issues of becoming a superhero. He not only has the confusion of what’s happening to him hormonally, he also has the confusion of what’s happening to him in his personal life, and on a societal basis as these huge responsibilities fall on his shoulders.”

Parker first experiences the effects of his organic web-shooters during lunch in his high school cafeteria, becoming mystified when a sticky web adheres his fork to his hand. When a second stringy strand accidentally shoots from his wrist and webs a lunch tray across the room, he realizes his life has begun to change. John Frazier’s physical effects team supplied the initial sticky strand using Caryton, a super-stretchy urethane, and created a range of physical webs throughout the film, developed after extensive testing during preproduction. All of the web-shooting effects, however, were generated digitally at Imageworks. “We developed a lot of web looks with Neil Spisak,” said Dykstra. “It was a long development process, but finally we selected a multiple-strand web that had a liquid feel to it. Once it struck, it did what we called ‘catalyzation,’ and changed characteristics from a liquid gooey state to a more solid form.”

Taking a lead from nature, Dykstra designed webs to be translucent, reflecting and transmitting light with lens-like qualities similar to nylon monofilament, but with complex physical parameters. “We wrapped several strands around one another,” Dykstra explained, “and then put a binder around the outside of that. The web came out as a series of strands; then, once it hit, it catalyzed and cinched down. The web look also varied hugely depending upon the environment. If we had a bright day exterior, we had to generate the web in a completely different way than in a night environment. And we sometimes had to match physical webs.”

For scenes requiring ropes of web and actors grappling with the sticky substance, Frazier team technicians George C. Stevens and Tom Frazier produced physical props with the same multi-strand design. “Production would tell us how long they wanted the web,” recalled Tom Frazier. “If they wanted thirty feet, we’d stretch out a strand of clear urethane to thirty feet, then we’d stretch about twenty strands after that to the same length. We then took a flexible epoxy and wrapped that around it. We also made tiny webs for the real spiders to walk on, made out of very fine nylon monofilament, like fishing line, laid one piece over another and hit each intersection with flexible epoxy.” Because the webbing scenes were photographed with no physical web present, the physical effects crew supplied the interaction of props wobbling on impact.

Imageworks CG supervisor Ken Hahn and senior 3D artist Theo Vandernoot designed web animation methodology that allowed artists to produce a variety of looks as the strands flew from Parker’s spinnerets and affixed to objects. “We had to create a lot of different thickness textures,” said Scott Stokdyk. “When Peter webbed the lunch tray, it was much thinner; when he swung from the web, it was much thicker. In some cases, the practical web looked a little too opaque, so we also replaced the webs in those scenes.” Web designs incorporated orb weaver web-spinning styles and elements of the original comic book designs, which portrayed web strands with gnarled and twisted qualities, suggesting hefty load-bearing capabilities.



Costume designer James Acheson updated Spider-Man’s suit while remaining faithful to the comic book original. Alec Gillis and Tom Woodruff, Jr., of Amalgamated Dynamics, lent their expertise to the building of twenty-eight suits – most of them one-piece spandex unitards, with hood, gloves and boots integral to maintain a skintight fit over a muscle suit worn by Maguire and his stunt doubles. Removable-hood versions were built for scenes in which the actor’s face would be revealed, a circumstance Raimi exploited as often as possible to ensure audiences would connect with the character.

To animate web extrusions, Vandernoot's web simulation employed a soft body dynamic produced in Houdini, using the software's new Vector Expressions interface. "We built a glorified spring system," said Vandernoot, "then we used Vex to do RenderMan-style programming — not just for surfaces and shaders, but also for mini-programs such as particle operations — and we wrote our own particle system." Tracking between source points on Tobey Maguire's wrists and target objects, animators designed web trajectories, then procedurally propelled virtual jets of particles from the spinnerets, dialing in physical attributes. "It had spring dynamics, gravity and a corkscrewing effect, for which we wrote a little proprietary code. We controlled how tight the spray was, how thick it was, how bubbly or 'noisy' it was, and its opacity as it tightened up."

CG webs incorporated a number of rendering tricks to realize the multifaceted design criteria. "If you go out in the morning and see a spider web," observed Stokdyk, "you might not notice it at first. The web is meant to disappear because spiders don't want the bugs they're catching to see it. When you do see a web, a lot of times all you see are little specular hits of light. So that became the most important component of our web design. We used a specular highlight to define the shape; and sometimes, to get more out of that, we added what John Dykstra called 'sun dogs' in the composite. These gave us tight, bright specular hits that ran along the strands as the camera moved. Then we had other layers, including an iridescent layer that created rainbow effects, splitting light into reds and blues and greens. We combined all those render passes in the composite, and then we used a compositing trick to add a refractive component. Seen up close, the web acts like a lens, distorting the background." Approximately ninety shots in the film featured web effects, animated by Vandernoot and a team of three.

Parker's strange new abilities gain unwanted attention in the school cafeteria, when Mary Jane Watson (Kirsten Dunst) — whom he has secretly loved since grade school — slips on a spill while walking past him carrying her lunch. Reacting with lightning speed, Parker saves the girl from falling and catches her apple, sandwich, milk and Jell-O back on her plate and tray. John Frazier's team staged the scene practically, using an overhead flying rig that allowed technicians to puppeteer the tray and foodstuffs above the actors, then drop them into place on Maguire's



Acheson and the ADI team also collaborated on the design and fabrication of the armored suit and helmet worn by the Green Goblin (Willem Dafoe), the masked alter ego of embittered chemical engineer Norman Osborn, Spider-Man's principal nemesis in the picture. When Osborn, in a desperate bid to win an important defense contract for his company, tries an untested performance-enhancing drug on himself, he develops a psychotic split personality that leads to murder and mayhem.

outstretched hand. Imageworks digitally speeded the moment of Parker's catch to a blur using Realviz ReTimer.

Parker exits the cafeteria in confusion, and enters a busy corridor where he experiences a sense of foreboding, his 'spider-sense' tingling in anticipation of danger nearby. The comic book depicted spider-sense with red rays radiating from Parker's head, or by occasionally superimposing the *Spider-Man* mask over half the character's head. The filmmakers sought out more cinematic concepts. "I had a lot of different ideas for spider-sense," observed Raimi. "The basic goal was to realize what was suggested in the comic books, which was that *Spider-Man* had a sense of things that were beyond our ken, unseen and unheard. One idea I had was to shoot the movie in 'scope, but to crop the sides of frame 99 percent of the time, then open it up in the few instances where he has spider-sense. I was quickly talked out of that! Finally, John Dykstra and my storyboard artists came up with the idea that we should use the camera to create the sense that Peter's spider-sense was looking around, searching. John then helped me crystallize this concept."

Dykstra's proposal for Parker's first experience with his spider-sense was to stop time around the character, the camera simulating his sensory point of view as it ferrets out a number of potential hazards and false alarms around him in the corridor. "Essentially," said Dykstra, "it was the concept of the expanded moment, only we took it beyond the standard still photography array and moved the camera within this environment into close detail inspection of components of the world around him, staying in motion." Aware of the audience's familiarity with 'bullet time' effects, popularized by *The Matrix*, and having created his own frozen moments for *Batman and Robin* even earlier, Dykstra gave the effect a twist in *Spider-Man*. "First of all, we didn't use still camera arrays because they limited us with regard to how we could move the camera. We wanted to be able to move from object to object, in close inspection. A still array generally allows you only to circumnavigate an object — as soon as you try to move in on an object, you have to make it out of CGI; otherwise, you end up with cameras seeing one another."



During the conceptual phase, artists at ADI created a prosthetic makeup for the Green Goblin that was a literal interpretation of the comic book character, and was capable of displaying a range of mechanically aided expressions. Though impressed by the result, Raimi nonetheless opted to go with a rigid helmet, citing the illogic of Osborn's having to apply a complex prosthetic makeup to himself before issuing forth as the Green Goblin. Artist Barry Koper applies a light wash of color to the animatronic test makeup, worn by Tom Woodruff.

To simulate a roving, dimensional perspective without digitally modeling the entire frozen environment, Dykstra employed motion control photography, in real time, then tracked layers of frozen motion detail into the live plate. "The motion control move allowed us to move the camera through our set," commented Dykstra, "making our 'forbidden' camera moves around the characters in what is now known as 'bullet time.' We then added computer generated imagery, extreme high-speed photography of actors and extreme low-speed photography of actors holding very still. It was a kind of cool explanation of 'spider-sense' — which was, by its very nature, an expanded moment."

Nic Nicholson — working with equipment and personnel from Camera Control of Santa Monica — set up the motion control shoot in a studio set of the high school corridor, which allowed camera access and the ability to remove walls. Utilizing data from an Imageworks Maya previz, Camera Control technician Simon Wakley programmed a Milo motion control rig to move from a 24-frames-per-second closeup of Maguire to a 6-frames-per second angle of the hallway, moving around actors holding positions and mime artists moving in extreme slow motion, before returning to real time. Other student performers were shot against greenscreen. Imageworks then tracked the elements together and digitally generated isolated details. “One character was frozen blowing a spit-wad through a drinking straw,” said Scott Stokdyk, “so we modeled the spit-wad and spit digitally, which enabled us to examine the textures close up and add a bit of motion with very limited depth of field.” Imageworks added a passing CG paper airplane, and a CG housefly that hovers above a CG school bell attached to a wall. Parker finally homes in on the real source of danger and dodges a punch from Flash Thompson (Joe Manganiello) — Mary Jane’s hothead boyfriend — in a shot that reverts to real time, with Parker’s body digitally accelerated in frame.

Unnerved by his new abilities, Parker heads home from school, then notices another aspect of his transformation as tiny barbed protuberances emerge from his fingertips, revealed in three jump-cuts into Maguire’s thumb. Photographed second unit, using a hand double stand-in, director of photography Don Burgess selected a laboratory printing technique to capture the first two super-macro closeups, mounting two Panavision 75mm lenses front element to front element and photographing the subject’s thumb one inch from the end of the lens. Second unit director of photography Christopher Faloona then employed a specialty long-focal-length macro lens to capture an even closer image, using strobe illumination to reduce the movement of the pulse in the stand-in’s hand. Dykstra dotted the thumb with black ink marker dots, which



ADI artist Greg Smith sculpts the backside of the Green Goblin helmet out of clay, fitting it to a fiberglass casting of the completed front section. The finished helmet featured iridescent ocular lenses, as well as adjustable lights inside the eye and mouth areas that could be dialed up to illuminate Willem Dafoe’s features behind the mask, when desired. The production wardrobe team and ADI would also build twelve Goblin body suits, each comprised of fiberglass armor pieces attached to a spandex undersuit.

Imageworks tracked and visual effects subcontractor Pixel Magic digitally removed. Imageworks then modeled thorn-like follicles, tracked these to the surface of the thumb, and animated them to grow — a scientific explanation for Peter Parker’s powers of spider adhesion. “Spiders have thousands and thousands of tiny hairs on their feet,” explained Steven Kutcher. “These hairs are so small they interlock with imperfections on an apparently smooth surface. It’s like if you take two really fine hairbrushes and put them together, the bristles mesh and stick.”

Parker tests his fingers’ adhesive properties by retiring to an alley and placing his hands on a sheer brick wall. Then he crawls hand-over-hand up the building, making contact with his fingers and his toes, and is thrilled to find he has scaled the wall. The alley scene featured one of six practical wall-crawling rigs created by the physical effects team, one of the earliest effects devised for the film. “When we started in May 2001,” John Frazier recalled, “nobody really knew how far we could go with

the practical *Spider-Man* and how much would be CGI. So we did a lot of tests at my studio in Sun Valley and came up with some pretty unique ways of making *Spider-Man* appear weightless as he was floating around the walls.”

Frazier and his team concentrated on improving standard mechanical wall-crawling technology, where the performer is either hauled up a building by a winch, or climbs across a horizontal building façade while being filmed by a camera tilted on its side. “Most of the time,” said Frazier, “when you have an actor climbing a wall on a wire, you can always see they’re pulling on the cable. Their body scrunches up. If the wall is lying flat, it’s always obvious by their posture that they’re lying on a wall. So we built a system where we had a horizontal wall dressed with windows, pipes and electrical conduit. We then suspended a platform from the ceiling, parallel to our horizontal set, which prescribed the way we wanted *Spider-Man* to crawl, say, zigzagging between the windows and the pipes. Then we mounted our flying rig to the upper platform, which rode along on air bearings.” The air bearings — small hovercraft-like pneumatic devices, used to maneuver heavy machinery in the aircraft construction industry — levitated the flying rig on the upper track, connected to an arbor that hung underneath, supporting the actor on a flying harness mounted at the hips. “Instead of hauling him about with cables, tugging him along from a trolley overhead and struggling with the friction of the pulleys on the track, we were able to float the actor about with no resistance. He propelled the rig, and was virtually weightless.”

Shot on soundstages in Los Angeles, the air-bearing wall rigs mostly featured *Spider-Man* stunt double Chris Daniels in the full body suit, though Maguire performed the physically demanding alley scaling scene assisted by Frazier’s rig and some digital wire removal. Maguire also performed greenscreen elements for closeups of his character swinging experimentally from his web, the actor wearing a flying harness concealed beneath his clothes. The harness connected to a cable that extended through Maguire’s sweatshirt at his shoulder, then connected to a twenty-foot section of urethane web. Maguire gripped the web and Pixel Magic digitally removed the cable that extended from his shoulder to his hands, creating the illusion the performer was supporting his own weight. “The wire from Tobey’s shoulder occasionally crossed his face,” stated Pixel Magic visual effects supervisor Ray McIntyre, Jr., “so we had to rebuild that using Adobe After Effects and Pinnacle System’s Commotion, sampling textures from the other side of his face, replicating his surprised expression and animating wind moving his hair.” Imageworks then created the final composite of Maguire swinging against a rushing background of digital buildings.



For shots of the Green Goblin aboard his combat-ready flying wing – known as the ‘Goblin glider’ to comic book fans – John Frazier’s crew attached a full-scale mechanized glider to a six-axis hydraulic motion base that provided yaw, pitch, roll, ascent, descent and spin, all actuated by a motion control system. In some cases, the prop was hung from an overhead flying rig capable of swooping the glider at speeds up to thirty miles per hour from an electronically controlled gantry. Willem Dafoe performed atop the glider for many scenes, secured to the device with safety cables at his back and boots clipped to ski-like bindings.

The sequence continues with Parker becoming more enthused with his new-found athletic prowess, and tracks with the exhilarated teenager as he shoots web and vaults rooftops. John Frazier's team constructed an elaborate mechanical rig for the scene, filmed on location in New York, which depicted Parker's overzealous employment of his abilities in a series of shots known to production personnel as 'Jump, Jump, Splat.' "They wanted to do as much as they could live," said Frazier. "Peter had to jump between these alcoves on a roof, leaping three parapets, six stories up on top of this rooftop in Queens. So we built this humongous truss, a long square tube of crisscross members, with a track that ran parallel with the roof, supported this between two cranes that stood at either side of the building, then hung a stuntman from the rig. As we moved him along, we controlled his ascent and descent on an electronic winch, while the camera rode another track, following him with New York in the background. Then, as he jumped the last parapet wall, Sam cut to a big billboard, and he splat right into it."

The practical stunt was ultimately exchanged for a digitally animated jump, which combined an Imageworks CG Peter Parker with background plates shot from the Frazier rooftop rig. "We did a lot of very effective dragging and pulling of actors on wires," noted John Dykstra. "Wire work is great for beginning a shot, or for ending a shot, but almost invariably if you slow an actor down in order to make a stunt doable, it shows. Unless you are making a stylized movie — like *Crouching Tiger, Hidden Dragon*, where they just said, 'Screw it, this is our lyrical style: our guys swingggg through the air!' — it doesn't work so well for entire shots, in my opinion."

As animated shots proceeded, the filmmakers arrived at a balance between physical and CG performance that led Imageworks to replace a number of other mechanically assisted climbing shots with digital animation. "We took a lot of our inspiration for wall-crawling poses from the artwork Glen Keane produced for Disney's animated *Tarzan*," stated Anthony LaMolinara. "When he attaches to a wall, he perches on the balls of his toes and his fingers. We ended up using our CG character for many of our wall-crawling scenes to create the correct pull of body weight down on his fingers and his feet." The wall-crawling scene became a proof-of-concept for LaMolinara and the Imageworks animation team, during an early screening for producers and studio executives. "We were looking at the wall test when producer Laura Ziskin remarked, 'I don't know, he moves like a man, but ...like a spider.' I slapped my hands together at that point, and said, 'We've got it!' Laura hadn't realized what she'd said, but it was a great moment because suddenly we knew that was how *Spider-Man* had to move."



Norman Osborn — in his debut appearance as the Green Goblin — blows up a vertical takeoff vehicle developed by his company's chief competitor. The shot featured a CG Goblin and glider composited into a live pyrotechnics plate. The digital Goblin was comprised of many individually modeled pieces of 3D armor. To provide some flexibility in the digital armored suit, Imageworks developed a muscle and surfacing system that simulated hard surfaces riding atop soft surfaces. Advanced shaders replicated the iridescent look of the practical suit and controlled the shading on each separate surface so that colors would change slightly depending on the camera angle.

Back home with his Aunt May (Rosemary Harris) and Uncle Ben (Cliff Robertson), smarting from his injury and the sight of Mary Jane leaving on a date with Flash, Parker sees a newspaper ad for a wrestling match offering a \$3000 prize to amateur fighters able to defeat Bone Saw McGraw (Randy Savage). Parker seizes the opportunity to convert his new super-strength into some immediate financial gain, and sews together a hooded costume from a red sweatshirt, stenciled with a spider logo created by assistant costume designer Lisa Tomczeszyn. Parker enters the tournament incognito, facing his opponent inside a wrestling ring. “Spidey doesn’t know what he’s getting into,” said John Frazier, “so as he gets into the ring with the other guy, the audience starts yelling ‘Cage’ and we lowered this huge cage around them. It was built out of aluminum, weighed about 5000 pounds, and was hydraulically controlled. The cage started high up in the permanents; then, as it came down, it closed to make a cube slightly bigger than the ring, about twenty-by-twenty feet.”

Trapped inside the cage, *Spider-Man* outmaneuvers Bone Saw and delights the crowd by flipping and leaping off the bars. The scene was achieved with stunt performers, supported through the cage by a pendulum wire rig. Practical flying effects were enhanced by Imageworks’ digital web-slinging, with wire removal and digital speed manipulation by CIS. “We ramped speeds from 24 to 31 and 39 frames per second,” CIS visual effects supervisor Ken Jones noted. “Speed change software works by calculating vectors of how an object moves and ‘averaging,’ or integrating, film frames. Where *Spider-Man* was flying across the wrestling cage, the software figured out a speed for *Spider-Man*; but it didn’t know what to do with the background, so it deformed the bars. We had to restore all that by hand.” Senior paint artist Larry Gaynor corrected the aberration by piecing bars back into place, sampled from elsewhere in the frame, then painting and evening out the grain in Avid’s Matador. Imageworks, Digiscope and Pixel Magic all contributed digital speed changes throughout the film to enhance *Spider-Man*’s athletic performance.

Peter Parker proves his skills in the wrestling ring, but when the fight promoter (Larry Joshua) cheats him of his prize, Parker chooses to ignore a thief (Michael Papajohn) who makes off with the promoter’s boxoffice takings. The incident takes on greater significance for Parker when he discovers his Uncle Ben shot dead outside the wrestling venue, murdered by the thief, whom he allowed to escape. The dramatic pursuit that follows — Parker dressed as *Spider-Man*, chasing his uncle’s killer through the nighttime city — featured twenty CG shots containing Cablecam background plates and digitally blended tiles of New York and Los Angeles, including all of Imageworks’ digital buildings, and the first extensive display of CG *Spider-Man* in action.

The sequence begins with Parker changing into his costume as he runs down an alleyway, then leaping onto a wall and scaling a building in a skittery spider-like fashion, realized digitally by Imageworks lead animator Spencer Cook. As Parker gains a view of the thief’s car departing below, the camera rotates and match-moves from a closeup of Maguire to a shot of the CG *Spider-Man*, who shoots a web, then leaps and almost hits a building, recovering just in time to avoid collision. “We really wanted *Spider-Man* to be a mess at first,” said LaMolinara. “We wanted people to see he’s trying to get his act together. He almost hits the wall, but doesn’t want to make that mistake again.” Parker lands on the cupola of a small domed building — a completely digital shot, featuring a CG cupola, facing building and street below. To populate the street, Imageworks provided secondary animation with 3D models of automotive and pedestrian traffic. Modelers built a library of twenty

CG vehicles for the film — sedans, taxis, police cars, delivery trucks — which animators hand-placed and animated in frame. Animators also used motion capture as basis for the creation of twenty CG passersby, modeled from photographic textures of Imageworks employees — including Stokdyk and LaMolinara — applied to a generic skeletal model, either placed by hand or animated with flocking systems leveraged from technology developed at Imageworks for *Harry Potter*.

Parker dives from the cupola in a long swooping shot animated by Jeff Lin. The camera then swings with him as he shoots three webs in succession, vaulting lampposts and displaying cloth dynamics developed by John Lee. “Bill Diaz animated the swinging shot chasing the thief’s car,” said LaMolinara. “The loose-fitting homemade costume was a great compliment to the animation here, because we read so much movement from the way clothes move. It really helped describe the speed and fluidity of his actions.”

While animating the nighttime chase scene, LaMolinara discovered an unexpected anomaly in the animation pipeline. “Because of the speed at which *Spider-Man* was traveling,” commented LaMolinara, “when we lit and rendered the low-resolution, flat-lit previz models as high-resolution, textured models, the apparent speed changed. The character seemed to move much faster, so we sometimes had to go back and slow him down. For daytime shots, we did not have this problem; but at night, when we applied all the glints of light flickering kinetically across *Spider-Man*’s body, it created the illusion of him traveling much faster.”

Parker lands on the hood of the thief’s car — a stunt vehicle rigged to jolt in motion beneath the impact of the digital character — and the pursuit continues on the ground, as the thief flees on foot and takes refuge in a warehouse. In a classic comic pose, *Spider-Man* descends behind his prey, silhouetted, inverted, arms tucked between his legs in a yoga lotus posture — a practical wire-rigged stunt — foreshadowing the thief’s demise as he attempts to flee the newborn superhero. Imageworks completed the sequence, and emphasized the isolation of Parker’s transformation by pulling back to reveal *Spider-Man* perched, forlorn, on a buttress of the Chrysler Building — digitally compositing Maguire atop an art deco gargoyle, tracking the live-action into the New York night tiles, and revealing the moonlit city below.

Spider-Man’s world is further complicated as Norman Osborn, father of one of Peter Parker’s high school friends, undergoes his own transformation at OsCorp Laboratories. Establishing shots of Osborn’s enormous industrial chemical plant — a completely fictional location — were created as a 3D matte painting by Imageworks digital artist Ivo Horvat, who shared matte painting duties for the film with David Bleich and Imageworks senior art director Marty Kline. Horvat developed a 3D model of the location from Neil Spisak’s designs, constructing a central curving office block and outlying chemical processing plant, then mapped the model with



The Green Goblin launches an attack on a ‘Unity Day’ parade in Times Square. Unable to shut down the actual New York City location for filming, the production opted to composite a computer generated Goblin, glider and balloons into a pan-and-tile virtual set, built from still photographs, laser data and multiple motion control tiles captured at the iconic site. Digital set extensions included a Unity Day sign to replace the prominent Coca-Cola logo

photographic and painted textures, live smoke elements and CG ground traffic.

on the Times Building and a fictional Empire Grand Hotel to replace the Marriott Marquis.

Inside his laboratory, Osborn demonstrates his latest invention, a levitating one-man flying wing, designed for combat and controlled by an operator wearing an insect-like, armored flight suit — which would become the Green Goblin suit. Osborn's flying vehicle was originally conceived by Stan Lee in *Amazing Spider-Man* #14 as a rocket-powered flying broomstick, but took form in later issues as a vicious-looking bat-winged contraption, familiar to generations of *Spider-Man* comic readers as the Goblin glider. Spisak and Dykstra strove to update the glider design in the same way that Acheson and ADI had updated the Goblin suit, capturing the spirit of the comic, yet giving it a modern spin. "We wanted the glider to be very agile," stated Dykstra, "and we wanted it to be more bat-like than bird-like, capable of radical maneuvers and odd darting motions. One of the things I tried to sell Sam on was the idea that the glider should move more like a snowboard, rather than an airplane flying from 'A' to 'B.' Another real-life parallel are the guys sky-surfing with 'grav boards,' used by extreme sports skydivers. I felt the personality of the Goblin's flight should be quite dance-like."

Conceptual artists Harald Belker, James Carson and James Martin, along with modelmaker Jason Mahakian, designed the Goblin glider as a six-foot winged platform attached to a central T-shaped fulcrum, incorporating rear and vertical thrust engines. Paul Ozzorio then sculpted and photographed a small clay model and generated a 3D representation of the glider using Rhino software. John Frazier's team generated CAD elevations, from which ten full-scale mechanized props were built. "We fed the CAD files into our computerized, five-axis router that carved all the parts," said Frazier, "so there was no on-set sculptor. Using the router enabled us to be very precise in the way the pieces fit together. There were so many fine details that it would have been very difficult to carve it all by hand and get a perfectly symmetrical registration. We cast most of the parts out of fiberglass, and some of them out of carbon fiber."

Lead mechanical engineer Mark T. Noel designed a six-axis hydraulic motion base on which the glider could perform yaw, pitch, roll, ascent, descent and spin, controlled by a Kuper motion control computer. Different versions of the glider were outfitted to perform a variety of actions. Among the mechanical features were custom-machined pistons that allowed wings to move independently as the glider banked, or to close together as the glider landed. Noel also built spring-loaded foot-plates on the surface of the glider wings that clipped to the Goblin boots like ski bindings, allowing the rider's feet to remain level when the glider wings folded underneath him, so the actor did not break his ankles. Other accoutrements included oxyacetylene-activated machine guns, rocket-propelled spears and a mechanical 'pumpkin bomb' dispenser that



popped baseball-sized grenades into the Goblin's hand. The pumpkin bombs, based on a design by Harald Belker, retained a semblance of the comic book jack-o'-lantern design. The Frazier team cast the bombs in resin, painted them to resemble brass and installed electronics that caused a ring of light-emitting diodes to flash around a central glowing button mounted on the top. The team also created rubber versions for tossing. All the glider parts were chrome-plated, and then painted with acrylics to create a deep, rich finish.

Mechanical gliders rode a Chapman crane on top of the motion base. In some instances, they were hung from an overhead flying rig capable of swooping gliders at speeds of up to thirty miles per hour, either suspended from a crane or from an electronically controlled gantry. "What was really surprising to me about the Goblin glider," commented John Frazier, "was that when we were first testing the glider rigs we had different stunt doubles riding them, and they were a little unsure and a little awkward. When we put Willem Dafoe on the glider, you'd have thought he was born on it! He did things that we never thought were possible." Dafoe, an experienced yoga practitioner, performed many scenes onboard the glider, despite being entirely covered by the Goblin costume. Wearing safety cables attached to his back, and boots clipped to the glider bindings, Dafoe threw himself into the role, anticipating motion base moves to Frazier team cues. "Willem had limited helmet visibility, so we'd say, 'Put your hand out now,' he'd hold out his hand and we would plop a pumpkin bomb right into it. He really got into it. He got down on that glider, just like he was a surfer going through the barrel of a wave; and he never appeared to be afraid, even though we sometimes had him flying around fifty feet up in the air. He made us look really good. I mean, I wanted to buy the guy lunch every day!"

For the glider's first scene in the OsCorp laboratory, in which Osborn displays the machine's performance-enhancing capabilities to skeptical military brass, the Frazier team floated the mechanical prop on the Chapman crane. Pixel Magic performed digital rig removal — painting out the motion base, six wires, a hydraulic umbilical the thickness of a man's leg, and a rear-mounted glider attachment point known as the 'butt pipe.' "The camera was jibbing down and tilting up," recalled Ray McIntyre, "so we not only had to rebuild all of the background details, the railings and the people in the lab, we also had to paint in a portion of the bottom of the glider." Imageworks then animated glider jet blasts, adding heat shimmer in the render, tracked to the completed shot.

The Goblin's first glider missile launch, as John Frazier and his crew built a scene that was a little bit of a challenge. (Kirsten Dunst) Interviewing the glider parts to a balcony with the physical effects team also built a support statue that crumbled on cue as the balcony collapsed on top of it – a one-take-only gag.



Spider-Man catches Mary Jane as she tumbles from the balcony. The shot was realized with wire-rigged stunt doubles, shot against greenscreen and composited into a live-action plate of fleeing extras. Wider shots employed the CG Spider-Man and a digital double of Kirsten Dunst, inserted into bright-daylight New York City plates. Since the CG Mary Jane would be seen in only a handful of shots in the picture, the model was built at a lower

Later at the laboratory, Osborn tests a performance-enhancing chemical on himself, anxious to secure his lucrative defense contract, and experiences a side effect that unhinges his already volatile personality. Second-unit physical effects supervisor Danny Cangemi and floor effects supervisor James Schwalm supplied smoke and pyrotechnic effects for the scene, combined with a stunt department wire rig that tugged a lab technician, thrown by the psychotic Osborn, through panels of breakaway glass. Imageworks provided digital wire removal and speed manipulation, while Digiscope digitally tinted the smoke green.

Osborn and the glider next appear at a remote desert location shot in a rock quarry north of Los Angeles. The setting posed as the secret testing ground for Quest Aerospace, an OsCorp competitor, which has eyes on a military contract with a vertical takeoff vehicle of its own, the Badger — another Frazier team creation. “The producers asked us if we could construct the Badger for ‘x’ amount of dollars,” said John Frazier. “We said ‘yes’ and built a vehicle a little like the old TV commercial Wienerschnitzel hotdog car standing on one end, which a guy could get inside. Then we took it out to location and blew it up.”

The Quest Aerospace dignitaries are surprised by the appearance of the Green Goblin who swoops in from the sky astride his glider and destroys both the Badger and the observation bunker. Imageworks placed the Goblin in the heart of the action, appearing through a ball of flames rising from the Badger as a full CG character on a CG version of the glider, overseen by Ken Hahn and senior technical director Albert Hastings. “We had great access to John Frazier’s glider prop,” commented Scott Stokdyk. “It was a very complex shape with a lot of different types of surfaces, some more reflective than others, with nice beveling patterns across them, for which we painted displacement maps. Our CG version was also articulated with machine gun flaps that opened, moving pistons and parts of the wing that could flap and turn in different directions.”

The Imageworks animation team imparted thrust from the glider’s vertical takeoff rockets, one beneath each wing, balancing this with more prominent rear-engine rockets and the Goblin’s body movements. “John Dykstra and I have both surfed quite a bit,” Anthony LaMolinara noted, “so we brought that mentality to the Goblin glider animation. We had several scenes where the Goblin kicked at the glider as he was flying, causing it to spin or turn in the same way that a surfer kicks off the top of a wave. It was all based on that kind of movement, though we did go back and forth with the physics. Sometimes we had to jump ahead of reality to suggest how powerful the glider was as the

resolution than those for Spider-Man and Green Goblin, which were more prominently featured. Spider-Man catches Mary Jane as she tumbles from the balcony. The shot was realized with wire-rigged stunt doubles, shot against greenscreen and composited into a live-action plate of fleeing extras. Wider shots employed the CG Spider-Man and a digital double of Kirsten Dunst, inserted into bright-daylight New York City plates. Since the CG Mary Jane would be seen in only a handful of shots in the picture, the model was built at a lower resolution than those for Spider-Man and Green Goblin, which were more prominently featured.



Answering a call for help from within a burning building, Spider-Man finds himself ambushed by the Green Goblin, who has vowed to destroy him. The scene featured live pyrotechnic effects and an all- CG Spider-Man deftly dodging the Goblin’s flying razorbats – hand-tossed bombs with lethal, scythe-like blades – in a slow-motion

Goblin moved about in the air, somewhat like a Harrier jump-jet. Other times the glider had a mind of its own. In one scene, the Goblin is knocked off his glider, the glider spins out of control, then the Goblin pushes a button on his suit and the glider comes back to get him. So in a way, it's like his pet."

Answering a call for help from within a burning building, Spider-Man finds himself ambushed by the Green Goblin, who has vowed to destroy him. The scene featured live pyrotechnic effects and an all- CG Spider-Man deftly dodging the Goblin's flying razorbats – hand-tossed bombs with lethal, scythe-like blades – in a slow-motion ballet. The spiraling razorbats – as well as falling embers – were digital components of the shot.

The Goblin's antics presented Imageworks animators with an interesting dichotomy in that they had to articulate the rigid suit and mask to emulate Willem Dafoe's highly expressive performance. "Both of our main characters had covered faces, which required us to show their emotions in the movements of their bodies," said LaMolinara, "but it was especially difficult with Green Goblin. *Spider-Man* had more of a moderated personality. Goblin was much more mercurial. He was up and down. One moment he was happy, the next moment he was crazy. He was an old man one moment, the next he was wicked, another time he was extremely athletic, then another time he was funny. He was all over the place! To show all those emotions in his body language was quite a challenge."

While Norman Osborn becomes acquainted with his new identity as the Green Goblin, *Spider-Man* begins to face his own responsibilities, fulfilling his uncle's last wish by thwarting crime on the streets of New York City in his newly designed, form-fitting costume. A montage of crime-fighting activity shows *Spider-Man* halting a grocery store holdup, foiling a payroll theft and interrupting a jewel robbery. John Frazier's team provided a net of extruded urethane web for a scene in which policemen arrive to find the would-be jewel thieves strung up in a Spidey web. In another scene, Mary Jane encounters a pair of armed thugs. *Spider-Man* uses his web to disarm the muggers — a practical wire gag that tugged the prop out of frame, combined with an animated Imageworks digital web — then swings down to street level to dispatch the hoodlums *mano a mano*. Raimi shot the scene with a Jeff Habberstad wire-pull ratchet gag that yanked a stuntman standing in for the mugger from frame. Imageworks then animated its CG *Spider-Man* to swing through frame and connect with the hoodlum at liftoff. The conflict continues with the fully CG *Spider-Man* leaping, flipping and kicking the criminals to a pulp. "We worked with some martial artists who did some wild fight routines for us," said LaMolinara, "but we backed away from that. We wanted *Spider-Man* to move in a 'spidery' way that a normal human couldn't, but Sam wanted there to be a fine line between what a normal human person could do, and what *Spider-Man* could do. We simplified his fighting style to the kind of moves that a normal person might be able to do given an extrasensory ability, like spider-sense."

When word spreads of *Spider-Man*'s activities, *Daily Bugle* newspaper publisher J. Jonah Jameson (J.K. Simmons) adopts an antagonistic stance, commissioning Parker to photograph the vigilante, and splashing headlines that question the masked man's motives. The reports coincide with Norman Osborn's abrupt dismissal from the OsCorp organization and his prompt decision to exact revenge on members of the board. During a festival organized by OsCorp Laboratories — a 'Unity Day' parade of giant balloons through Times Square — *Spider-Man* is forced to take action when the Green Goblin appears on the scene.

The Unity Day parade and the Green Goblin's ensuing attack called upon the full arsenal of the visual effects and practical effects teams' resources. Early in preproduction, it became apparent that it would be impossible to shut down Times Square for shooting. Dykstra's team surveyed the historic intersection with still photographs, laser data and 26 motion control tiles taken from the balcony of the Marriott Marquis Hotel overlooking Broadway. Imageworks then rebuilt the area as a virtual set, adding digital set extensions that included a Unity Day sign in place of the prominent Coca-Cola logo on the prow of the boat-shaped Times Building, and a fictional Empire Grand Hotel in place of the Marriott. For closeups of privileged onlookers on The Empire Grand balcony — including Mary Jane and her new boyfriend Harry Osborn (James Franco), son of Norman and a close friend of Parker — Neil Spisak's team built a full-scale, five-story hotel façade on a soundstage in Los Angeles. To fill the streets with crowds, bleachers full of onlookers and a rock concert in front of the Times Building, Spisak also designed an open-air street location in Downey, California, backed by two-story-high perimeter walls. Dykstra's team photographed the set from high angles, then digitally inserted this into the virtual Times Square set. "We stitched together tiles of New York in the top and the right side of the frame as you look towards the Times Building," Scott Stokdyk said. "We split the Downey set into the foreground, with our CG hotel to the left of that. Then we added our CG balloons in the midground, floating over the parade, which helped hide the joins."

Imageworks modeled seven digital balloons to bob and sail above the parade, anchored by CG ropes to practical cruising floats. Based on art department designs, each balloon portrayed a happy, smiling character representing international brotherhood — including an Australian kangaroo, a Chinese panda, a jolly Russian Cossack and a Bavarian in lederhosen. "There was a live-action version of the Bavarian balloon on set," Stokdyk recalled, "but it didn't end up being used in any of the shots. We talked to the guy who built it about how they made these balloons — where they seamed the patterns and where the wrinkles occurred — and we based all our textural wrinkles on that. Dan Kramer set up the animation system using lattices and dynamics to connect the balloons to their ropes, so they undulated and bounced around."

The balloons became a story point in the sequence.

After the Goblin begins barnstorming the crowd, Peter Parker ducks out to reappear as *Spider-Man*, then leaps after the Goblin, bounding from balloon to balloon like stepping stones. "Dan Kramer and Tom Pushpathadam did a lot of beautiful work with the balloon dynamics and lighting," related Anthony LaMolinara. "We key-frame-animated our digital *Spider-Man* to leap between three balloons, and the balloon dynamics showed the energy resonating through each surface as he hit, wobbling the limbs. It was much more efficient than spending day after day animating those effects by hand."



Full-frame shots of Imageworks' CG Green Goblin were also featured in the film. In an attempt to lure Spider-Man to his death, the villain abducts Mary Jane and holds her hostage atop an anchor tower of the Queensboro Bridge. Computer generated performers, or live actors on partial stage sets, were inserted into a complex digital reconstruction of the bridge. A succession of still and moving images, photographed from two 300-foot cranes at the actual New York location, aided in the construction of the digital set and were tiled together to provide additional backgrounds.

Goblin next displays his destructive tendency by tossing a pumpkin bomb at onlookers on The Empire Grand balcony and vaporizing six OsCorp board members in a flash of orange light. Imageworks created the vaporizing blast for a one-off vaporizing shot that displayed the painful effects of being pumpkin-bombed. Digital artists roto-scoped the victims reacting to an on-set lighting effect, then modeled and match-moved 3D skeletons to a plate of the empty background, matching the actor's moves with skeletons and dissolving off the performers in an orange glow. John Frazier's team created other pumpkin bomb effects with practical pyrotechnics, occasionally enhanced by Imageworks digital debris and dust to keep destruction consistent from shot to shot.

For a climactic moment in the attack, Green Goblin swoops toward The Empire Grand, fires his glider missiles and strikes a giant supporting statue, causing the hotel balcony to collapse. Imageworks animated wide shots of the Goblin's approach and inserts of his missiles. For closeups, Frazier's team flew Dafoe on the wire-flown glider, its wires later removed by Pixel Magic. The collapsing balcony was a full-scale physical effect. "We built the balcony on hydraulic rams," Frazier said. "It was all computerized, so we could control how it broke away when we detonated the pyro. We also built the big statue of Hercules underneath to crush on cue so that parts would crumble as the balcony went down. It was all supposed to be marble, which Sam wanted to break and fracture." Based on an art department sculpture, the collapsing statue took months to prepare at Frazier's studio, and was consequently a one-take deal. "We constructed it out of pyrocel, with sections cast in fiberglass, built over computer-controlled hydraulic rams. We put little pieces of primer cord in the pyrocel, so as the rams squeezed down, the fiberglass pieces fell off; and when we blew the charges, the pyrocel fractured and spat pieces out."

Framed in closeup, Mary Jane reels from the balcony explosion as Spider-Man swings down in a graceful arc, kicking the Goblin off his glider toward the street below. The glider spirals out of control, spewing smoke, and pierces a large balloon shaped like the earth. Frazier's team executed the balloon piercing as a practical effect featuring the prop glider and a forty-foot-diameter cold air balloon built by South Dakota inflatable manufacturer Tom



During the climactic sequence, a missile launched by the Green Goblin from his glider causes a fireball that engulfs the motorist-packed lower deck of the bridge, a full-scale set designed and built in Los Angeles by Neil Spisak and his crew. The production stunt team staged an automobile pile-up on the set, shot against a black backing. Artists at Digiscope then composited an enormous live fireball into the plate, animating interactive lighting on the cars.

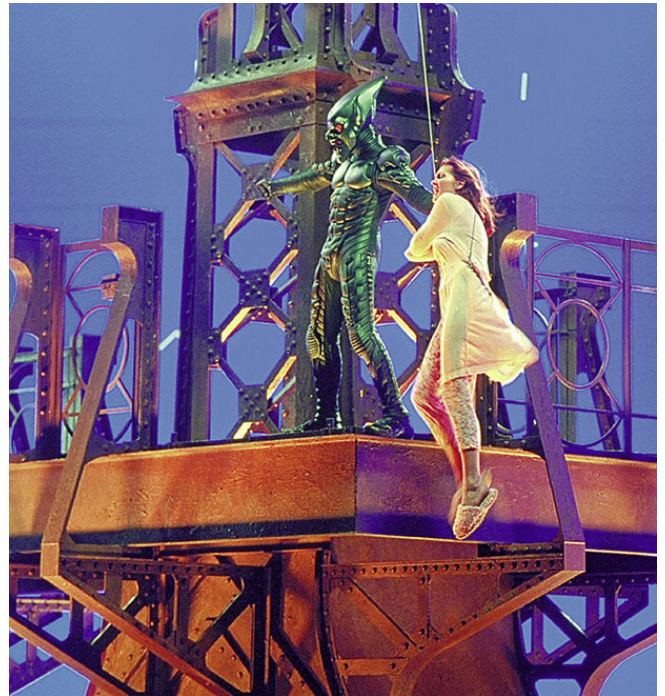


During the climactic sequence, a missile launched by the Green Goblin from his glider causes a fireball that engulfs the motorist-packed lower deck of the bridge, a full-scale set designed and built in Los Angeles by Neil Spisak and his crew. The production stunt team staged an automobile pile-up on the set, shot against a black backing. Artists at Digiscope then composited an enormous live fireball into the plate, animating interactive lighting on the cars.

Pushpathadam. Imageworks artist Jeff Wolverson digitally generated the Goblin glider smoke and contrails using 3D particle animation designed to carve menacing swaths through the sky.

Digiscope then composited an enormous live fireball into the plate, animating interactive lighting on the cars.

The disabled balloon causes the concert stage to collapse, scattering the crowd. CIS, Pixel Magic and Digiscope all supplied rig removal for the scene, painting out Goblin glider wires and the motion base rig, and restoring chaotic backgrounds of darting crowds and swirling debris kicked up by Goblin's low-flying glider. For one wide shot of fleeing bystanders, filmed in the Downey street location, the Pixel Magic artists digitally removed a secondary camera crew caught in the frame, then plugged the hole vacated by the team by digitally cloning members of the crowd to the restored section of the street. For a low angle of the bandstand collapsing, sun flaring into camera, Digiscope artist Fortunato Frattasio preserved a natural lens flare across a live-action shot of the falling bandstand, adding a bluescreen element of John Dykstra fleeing, and a foreground layer of a small boy about to be flattened. "That was John's big cameo," revealed Sam Raimi. "I made him run like a coward past this boy that *Spider-Man* has to save!"



After blowing up the Roosevelt Island Tramway wheelhouse – adjacent to the bridge – and catching a cable car filled with children plummeting towards the East River, the Green Goblin taunts Spider-Man with an ethical dilemma, holding the tram cable in one hand and Mary Jane in the other, then dropping them both simultaneously. Willem Dafoe and Kirsten Dunst performed on a bridge tower set piece, the latter dangling from a wire subsequently removed from the shot.

Imageworks' digital *Spider-Man* swings into frame to scoop the child to safety. On the bluescreen stage, the stunt team executed a wire-pull gag with Jeff Habberstad's son, Shane, and a stunt *Spider-Man*. Imageworks then composited the two into the live-action plate of the collapsing balloon. *Spider-Man* then springs to save Mary Jane from the collapsing balcony, achieved similarly, with stunt performers Mark Wagner and Jeri Habberstad on another wire rig. In three swooping shots, *Spider-Man* carries Mary Jane aloft and sails with her to safety. The wider shots of the rescue required Imageworks to construct a digital double of Kirsten Dunst and insert it into live New York plates, shot against a bright daylight sky. "We did not build a detailed model of Mary Jane," Anthony LaMolinara said. "She was a much more simple model than our two main protagonists because we only used her from time to time."

Closing out the Unity Day sequence, *Spider-Man* swings with Mary Jane around the shining white gothic structure of Saint Patrick's Cathedral, then gracefully deposits her, in one unblinking daylight shot, on a nearby roof garden atop Rockefeller Center. The scene was photographed as an empty plate on location in Manhattan, a live camera move that panned and tilted across the church. Imageworks tracked the shot in 3D, then staged a greenscreen shoot for the closing moments, photographing a *Spider-Man* stunt double dropping into a foreground set with Dunst. Animators then timed animation of the characters' CG doubles to swing into frame from camera left, passing behind St. Patrick's spires, with 'sun dog' glints sliding up the web. This then dovetailed into the live rooftop element, tracked into the plate.

Spider-Man takes his leave of Mary Jane, leaving the girl smitten. *Daily Bugle* coverage of the Unity Day events prompts Norman Osborn — suspicious of the newspaper's connection with *Spider-Man* — to visit J.J. Jameson in Goblin guise. For the character's dramatic entry, John Frazier's team rigged Jameson's office window to implode using pyrotechnic and air mortar devices, coinciding with a stunt performer riding the Goblin glider through the window on the Chapman crane. The Goblin, still aboard his glider, interrogates Jameson while airborne, lifting the terrified newspaperman by the scruff of his neck. Willem Dafoe performed the scene inside the Goblin suit on the crane-mounted motion base glider, while the stunt team hoisted Jonathan Simmons on a flying harness wire fed through the ceiling of the set. CIS provided digital wire and rig removal. *Spider-Man* arrives in time to save Jameson, but becomes annoyed at the chatty publisher's loud-mouth proclamations. "Jameson is a pretty obnoxious talker," said Scott Stokdyk, "so *Spider-Man* webs him in the mouth. Theo Vandernoot animated a completely digital web splat."



Sam Raimi directs occupants inside a practical replica of the cable car, mounted on a motion base and filmed against greenscreen.

Spider-Man next responds to an emergency call in a burning building, and finds himself confronted with an ambush. Filmed on location in central Manhattan, the scene featured live pyrotechnic effects co-rigged by Frazier's team and the New York construction crew. "The New York Fire Department and the Mayor's Office of Film, Theatre and Broadcasting were amazingly helpful in finding us a location," said John Frazier. "It took about two weeks to pre-rig the building with fire bars. The New York construction guys put a fireproof façade on the front of the building, and built fire hoods on all the off-camera windows. These were like sheet-metal chimneys that extended out the windows with about a foot gap at the bottom for the draft. They vented the heat and prevented the fire going up the walls, which were also protected; so, in the end, there wasn't even any smoke damage to the building."

Imageworks supplied *Spider-Man*'s arrival on the scene, with effects animator Todd Boyce creating a heat convection effect as the CG character detaches from his web. "We kept the little vertices where the web stuck to the wall," observed Theo Vandernoot, "then we applied negative gravity to simulate the current of hot air rising from the fire. It caused the web to flail very realistically in the air like a flag." A CG *Spider-Man* enters the flames and emerges again in a huge ball of fire, protecting a CG baby bundle. Landing on the street, *Spider-Man* returns the baby to its mother — a live wire gag shot in Manhattan — then returns to the burning building, believing it to be still occupied. Inside, the Green Goblin attacks *Spider-Man* with flying razorbats — pumpkin bombs that spring lethal scythe-like blades — which the digitally animated *Spider-Man* dodges in an elaborate slow-motion ballet. *Spider-Man* suffers a glancing blow, but continues his battle with the Green Goblin until he is forced to withdraw from the intense heat.

Following the battle in the burning building, Peter Parker barely makes it home in time for Thanksgiving dinner, web-slinging his way back to his new apartment, where he has taken up residence with Harry Osborn. Tracked and panned into a live-action plate of the apartment building, the CG character cuts to a stunt double performing a back flip entering the window of Parker's apartment set. Using editorial sleight of hand, the shot then cuts to Maguire as *Spider-Man*, standing and removing his hood. The camera then whip-pans to the door to reveal Norman and Harry Osborn arriving with Parker's Aunt May and, in a deft reverse cut, follows Norman into the room where Parker has now vanished. The camera tilts up to reveal Parker clinging to the ceiling above Osborn's head, unseen, but hoodless. The stunt team bound Maguire to the ceiling for the Hitchcockian reveal. Tension mounts as a digitally animated drop of blood leaks from Parker's razorbat wound. Timed to fall in slow motion, narrowly missing Osborn's head, the blood — animated with tiny fluid dynamics by Dan Kramer — impacts in a low angle on the wood floor.



Spider-Man leaps from the top of the bridge to catch Mary Jane and the plummeting cable car. On the greenscreen stage, *Spider-Man* stunt double Mark Wagner was filmed slow motion as he ran and performed a swan dive from a bridge girder set. That element was composited against a New York night sky — a digital pan-and-tilt replication.



An unbroken half-minute-long swing through the streets of New York brings Spider-Man to a stylish close. Though largely computer generated, the shot incorporated some live-action plate photography, staged in downtown Los Angeles. A remote-controlled camera was suspended on cables between two cranes and flown a full city block, descending to a few feet above the pavement, then soaring up again to provide the basis for a camera point-of-view following the arachnid superhero. The live-action plate was then extended with scores of digitally fabricated buildings for a nonstop sweep through the upper elevations of the New York skyline. Spider-Man, an all-CG character throughout the final shot, was animated to hit a succession of classic comic book poses.



An unbroken half-minute-long swing through the streets of New York brings Spider-Man to a stylish close. Though largely computer generated, the shot incorporated some live-action plate photography, staged in downtown Los Angeles. A remote-controlled camera was suspended on cables between two cranes and flown a full city block, descending to a few feet above the pavement, then soaring up again to provide the basis for a camera point-of-view following the arachnid superhero. The live-action plate was then extended with scores of digitally fabricated buildings for a nonstop sweep through the upper elevations of the New York skyline. Spider-Man, an all-CG character throughout the final shot, was animated to hit a succession of classic comic book poses.



An unbroken half-minute-long swing through the streets of New York brings Spider-Man to a stylish close. Though largely computer generated, the shot incorporated some live-action plate photography, staged in downtown Los Angeles. A remote-controlled camera was suspended on cables between two cranes and flown a full city block, descending to a few feet above the pavement, then soaring up again to provide the basis for a camera point-of-view following the arachnid superhero. The live-action plate was then extended with scores of digitally fabricated buildings for a nonstop sweep through the upper elevations of the New York skyline. Spider-Man, an all-CG character throughout the final shot, was animated to hit a succession of classic comic book poses.



An unbroken half-minute-long swing through the streets of New York brings Spider-Man to a stylish close. Though largely computer generated, the shot incorporated some live-action plate photography, staged in downtown Los Angeles. A remote-controlled camera was suspended on cables between two cranes and flown a full city block, descending to a few feet above the pavement, then soaring up again to provide the basis for a camera point-of-view following the arachnid superhero. The live-action plate was then extended with scores of digitally fabricated buildings for a nonstop sweep through the upper elevations of the New York skyline. Spider-Man, an all-CG character throughout the final shot, was animated to hit a succession of classic comic book poses.

Osborn and Parker meet again at dinner, Peter explaining his injured arm with a story about having been hit by a bicyclist. Osborn recognizes the injury as *Spider-Man's* razorbat wound and decides to test his suspicions. The Green Goblin is next seen paying a visit to Parker's widowed guardian, Aunt May, blasting through the roof and wall of the elderly woman's bedroom while she is kneeling in prayer. Frazier's team created the window implosion as two separate elements, first destroying a full-scale background of the bedroom wall, then providing dust and air mortar effects in concert with lighting effects for a greenscreen foreground element of May at her bedside. Imageworks united the elements with additional dust and flame effects. May is traumatized, but survives the event. However, Parker does not heed the warning, and is soon dismayed to learn that Mary Jane has disappeared.

An out-of-focus closeup sharpens to reveal an unconscious Mary Jane, then pulls back as she wakes to find herself on top of one of three anchor towers of the Queensboro Bridge, high above the East River. Spanning Roosevelt Island and connecting the boroughs of Queens and Manhattan, the double-decked, cantilever structure becomes the setting for a superhero showdown in which Green Goblin also endangers the lives of passengers on the Roosevelt Island Tramway, a cable car that runs parallel to the bridge.

The complex sequence called for a variety of practical and visual effects that enabled Raimi to stage dizzying angles of performers clambering about the structures. Dykstra first planned to photograph background plates on location, per the storyboarded plan, then introduce the characters using digital animation and composites of actors in partial sets. "We were supposed to climb the bridge, put our cameras up there and photograph from the bridge itself," related Dykstra, "but 36 hours before we were supposed to start shooting, permission was denied. So we rented two 300-foot cranes, brought



An unbroken half-minute-long swing through the streets of New York brings Spider-Man to a stylish close. Though largely computer generated, the shot incorporated some live-action plate photography, staged in downtown Los Angeles. A remote-controlled camera was suspended on cables between two cranes and flown a full city block, descending to a few feet above the pavement, then soaring up again to provide the basis for a camera point-of-view following the arachnid superhero. The live-action plate was then extended with scores of digitally fabricated buildings for a nonstop sweep through the upper elevations of the New York skyline. Spider-Man, an all-CG character throughout the final shot, was animated to hit a succession of classic comic book poses.



An unbroken half-minute-long swing through the streets of New York brings Spider-Man to a stylish close. Though largely computer generated, the shot incorporated some live-action plate photography, staged in downtown Los Angeles. A remote-controlled camera was suspended on cables between two cranes and flown a full city block, descending to a few feet above the pavement, then soaring up again to provide the basis for a camera point-of-view following the arachnid superhero. The live-action plate was then extended with scores of digitally fabricated buildings for a nonstop sweep through the upper elevations of the New York skyline. Spider-Man, an all-CG character throughout the final shot, was animated to hit a succession of classic comic book poses.

them up next to the bridge and used motion control to photograph a very rapid set of accurate tiles.”

Nic Nicholson and Camera Control photographed the motion control tiles using two Libra heads atop the cranes, controlled by a ground-level Gemini system, shooting simultaneously to match natural lighting and weather conditions. Although the background tiles were used for a number of shots, Dykstra and Imageworks also relied upon still photographs taken during the preproduction scout to model a 3D reconstruction of the immense and architecturally complex bridge. “It was a huge undertaking,” observed Stokdyk, “but the bridge factored into so many shots it was really worth it. After principal photography was completed, the scene was changed to punch up the drama and add more action, and having a 3D bridge enabled them to conceive shots from scratch.” The 7449-foot-long, 50,000-ton expanse of steel trusses and stone presented Stokdyk’s modeling and texture teams with a variety of technical challenges. “We had so many girders and intersecting beams, we decided to generate a lot of those procedurally to try to make our model less geometry-heavy. But as soon as we did that, we had to match the apparent levels of detail in the different types of surfaces. The upper metal part of the bridge had a lot of smooth flat shapes, so we gave those areas lots of little dents and specular hits. Then the underside of the bridge, where the stone truss was close to camera, had very bumpy, grimy surfaces. So we had to balance sharpness, contrast, hue variation and textural detail with all the detail in the geometry. That was the real challenge, once we got past the architectural complexity.”

For views of frightened commuters on the bridge’s lower deck, Neil Spisak designed a full-scale reconstruction of a stretch of the roadway encased by girders, wide and long enough to accommodate a full-scale automobile pile-up, which was built and filmed in Los Angeles. Also constructed was a section of the upper tower for Green Goblin and Mary Jane and their stand-off with *Spider-Man*. John Frazier’s team built a 10,000-pound, full-scale reconstruction of the Roosevelt Island Tramway car, capable of carrying performers on a cable back and forth across a Los Angeles soundstage. For shots at river level, Frazier’s team also built a full-scale river barge, mounted on air bearings the size of manhole-covers, which allowed technicians to manually shunt the 25,000-pound prop around the stage.

For the first shot in the sequence, Dykstra photographed Kirsten Dunst waking on the partial bridge tower set, the camera rising to a down-view of the scene with a bluescreen backing. Dunst, wearing a wire harness beneath her costume, teetered at the precipice as the floor effects team buffeted her with air movers. Imageworks tracked and composited the live-action element into a corresponding move on their 3D bridge, lit with hundreds of moody points of light, animated with CG traffic. Also included was a digital East River assembled from location photography and brought to life with sparkles, waves and ripples cloned from live water footage. Texture painters built the far distant New York City skyline from location tiles of the nighttime city projected onto a virtual dome with painted night sky textures.

Mary Jane spies the Goblin on his glider, swooping past the bridge, and watches in horror as he fires a missile at the Roosevelt Island Tramway wheelhouse and blasts it to smithereens, causing a cable car filled with children to plummet towards the East River. While Imageworks animated wide angles of the Goblin’s attack, complete with smoking contrail and a fiery green missile, Hunter/Gratzner

Industries and Grant McCune Design contributed to the missile's impact by obliterating the building in miniature — one of the few sequences in the movie to involve practical miniature effects. “The tram wheelhouse was an actual location,” remarked HGI producer David Sanger. “John Dykstra photographed it with interactive lighting, then gave us his Vistavision plates. We put the frames in our camera and did a one-to-one lineup with an eighth-scale miniature of the building constructed by Grant McCune’s team. It was the most effective, and most cost-effective way to do it.”

The explosion evolved in postproduction, becoming an expansive pyrotechnic moment that clued *Spider-Man* to the Goblin’s whereabouts for a final showdown. To maximize the impact of the physical explosion, HGI selected Mystery Mesa in Agua Dulce, California, for the miniature shoot — a rural location ideal for its dark skies and uninterrupted horizon. “The largest wheelhouse structure was pretty much the width of a truck,” said GMD foreman Monty Shook, “so it would have been impractical to build it any larger. We knew it had to go through a couple of explosions, so we designed it to be pretty rigid. We built the skeleton of the wheelhouse out of one-inch-square tubular steel. Some of the sections were modular so we could replace them between takes, and we made the skin out of corrugated aluminum. We made a corrugator out of two meshed wheels that embossed the corrugation into the aluminum sheeting as we fed it through, and we then individually glued those to the steel frame so when it exploded all the pieces would bend and fly off realistically.” Five modelmakers detailed the construction with miniature signage, soda machines, trash receptacles, bus benches, turnstiles, sodium vapor lamps milled from aluminum and lit with 35-watt halogen bulbs, and interior I-beams made out of fiberglass to withstand the intense heat of the blast. After six weeks of construction, Shook and lead designer Jack Edjourian mounted the wheelhouse on a 75-foot-square platform at Agua Dulce, landscaped to match the New York plates and dressed with manzanita and silk foliage to represent trees.

Imageworks provided a digital previz depicting the choreography of the Goblin’s attack. Director of miniature photography Tim Angulo then shot the miniature using two high-speed Mitchell cameras and one high-speed Vistavision Wilcam, the larger Vistavision format allowing Imageworks to digitally crop into frame and pan with the Goblin’s flyby. Richard Helmer provided pyrotechnic effects, collaborating with GMD mechanical designer Bill Shourt to create a highlight of the effect, seen in the Vistavision plate, when the tram pull-wheel explodes through the wheelhouse wall and rockets close by camera. “We used an air mortar to blow the pull-wheel through the aluminum breakaway wall,” Shook said. “We made the pull-wheel out of plywood. It weighed about forty pounds and was about three feet in diameter. Then we welded together a two-inch piston out of cold rolled steel pipe and cemented that to the ground in back of the pull-wheel. The wheel was hidden inside the miniature, on a little slide, held between a couple of guide-pins. Richie Helmer then shot it out of the air cannon from its mount so it would blow out the upper section of the tram station, ripping through the aluminum wall and spinning past camera.”

The first test on location sent the pull-wheel sailing out of sight; but after four trials, Helmer calculated the correct air pressure to choreograph an appropriate trajectory with split-second timing. “We figured out that the final duration of the explosion was 870 milliseconds, with the Wilcam at 160 frames per second,” explained Helmer. “I used half a gram of black powder to launch the wheel, and used black powder to create bright spots around the miniature to simulate electrical panels blowing up. It was mostly a fuel explosion, with about thirty channels of explosions to

articulate it. John Dykstra didn't want it too 'jerby' — which is the term we use to describe the little burning devices you see at firework displays. Jerbs can really mess with scale."

The explosion also included a high angle looking down on a miniature tram tower, into which Imageworks added a CG flailing severed tramway cable. This intercut with shots of a bus with its windows blowing out — an aluminum eighth-scale miniature, with working suspension and rubber tires, built by Rick Won — which was intercut with the full-scale practical tram, and occasionally a CG version. "Wherever production could shoot the real tram and stunt performers, they did," observed Stokdyk. "Whenever it was full frame, the tram was real. When motion was too extreme, or if we had all-CG shots that weren't composed in time for the practical shoot, we went CG and added hand-animated people inside."

Adding to the chaos, a fireball from the explosion rises and engulfs the lower deck of the bridge, causing a pile-up of commuter traffic. The Habberstad stunt team staged the auto pile-up on the full-scale set, with a black backing. Digiscope then composited the enormous fireball behind the lattice of intersecting girders, animating interactive lighting effects reflected in the careening cars. "Lawrence Carroll, Brent Prevatt and Fortunato Frattasio added highlights, reflections, changed the color, warmed up the bridge, and did a ton of roto work in Inferno," said Digiscope visual effects supervisor Brad Kuehn. "We took reflections of the bridge and mapped those onto 3D replicas of the cars. That way, as the cars turned and moved, the reflective surfaces warped and reflected in perspective. We did a lot of reconstruction, flashing the frame here and there, dissolving girders away to make the fire appear to seep through, adding little hints of red to the drivers inside the cars, and time-warping some of the collisions."

Across the city, *Spider-Man* is still searching for Mary Jane when he pauses on the rooftop of the Dakota Building near Central Park, seeing the fiery destruction out on Roosevelt Island, across the river. To propel himself across the distance, *Spider-Man* spins web and improvises a human catapult between two flagpoles on the Dakota roof. Conceived by Dykstra and LaMolinara during postproduction as a means of accelerating the action, the sequence featured another practical miniature by McCune Design. HGI first discussed shooting the scene as a cable flown camera shot, flying in real time at 72 frames per second over a large-scale miniature, allowing Dykstra to shoot live flapping miniature flags. When it became apparent that camera stabilization problems outweighed the benefits of a real-time physical interaction, Dykstra elected to add the flagpoles digitally, and HGI set about designing the shot as a multi-pass motion control shoot, at a smaller scale.

Grant McCune designed the Dakota miniature at eighth-scale, using stock photo reference of the gothic Manhattan apartment building. Imageworks created a digital previsualization of the camera move, then Jack Edjourian again led construction at GMD with Monty Shook. Modelmakers fabricated the main shape of the building out of medium-density fiber board, and detailed the roof with sculpted moldings and three elaborate dormers, projecting from the roof, covered with foliated ornamentation. Artists cut miniature shingles from Sentra and hand-laid them to the roof, and fitted curtained window frames with microscope slides to reflect light correctly. Construction was completed in a week and a half.

Using motion control data converted from Imageworks previz and fed into the Kuper controls, Tim Angulo photographed the miniature over two days on HGI's motion control stage — formerly Chandler Studios — using black backing for beauty lighting passes and greenscreen backing for matte passes. Dykstra selected three angles — a whip pan to and track in on the rooftop, an angle that peered over the far edge of the roof, and a reverse angle as *Spider-Man* launched himself toward the bridge. Imageworks then added digital flagpoles, web, *Spider-Man* and an establishing view of the CG bridge and city built from live-action tiles and CG buildings.

Spider-Man's flight lands him on the Queensboro Bridge, where he webs and swings and spins through the grimy girders as if on a jungle gym, then lands heroically on an upper tower — animated by Bill Diaz for the swing and James Parris for the landing. Face to face with *Spider-Man*, the Green Goblin preys on the crime-fighter's moral code, tempting him to choose between saving Mary Jane and the occupants of the tram. Imageworks composited the scene using a shot of Willem Dafoe as the Goblin on the bridge tower set holding the tram cable in his right hand, and Mary Jane in his left — Dunst in reality dangling from a concealed wire rig — with a CG *Spider-Man* observing from below. As the Goblin converses with *Spider-Man*, animators digitally animated his helmet eye coverings to open, revealing Willem Dafoe's eyes to emphasize his dramatic delivery.

The Goblin simultaneously releases the tram and Mary Jane, and Raimi punches in for a dramatic closeup of *Spider-Man*. Framed with comic book panache, the closeup featured the practical mask with eye-coverings digitally reflecting, on the right, the image of the falling CG tram and, on the left, the image of Mary Jane dropping Hitchcock-style from camera via a bluescreen wire-rig composite. *Spider-Man* leaps to his left — stunt double Mark Wagner filmed in a slow motion run and swan dive on the greenscreen girder set, digitally composited against the New York night sky. *Spider-Man* then falls, catches Mary Jane, shoots a web back over his shoulder, swings beneath the bridge and catches the tram cable in a stomach-dropping series of shots that plummet around the bridge. The shots incorporated a CG bridge with a practical daylit stunt of Jeri Habberstad and Mark Wagner taking a 180-foot dive, photographed by Nic Nicholson with the Camera Control motion control system. The stunt performers were attached to a pneumatically-controlled decelerator and framed against blue sky as they leapt from a precipice in Palos Verdes, California. The physical effects team then supplied a full-scale urethane web with a steel cable core for subsequent shots of *Spider-Man* webbing and lowering the full-scale tram and Mary Jane onto the full-scale barge.

Swooping out of the night sky, whirling a cable over his head like a bola, the Goblin then rockets into shot and snares *Spider-Man*, rips him from his web, and flies across the river, *Spider-Man* trailing behind. In a wide, hurtling tracking move retreating from the bridge, the camera pans with the Goblin to reveal an abandoned building on Roosevelt Island. Built from live plates of a practical location — a derelict Civil War-era smallpox hospital — Imageworks extended the CG bridge set to include the CG island and building as the Goblin swoops in low and smashes *Spider-Man* into a brick wall. Carl Hooper added a shower of bricks via particle animation.

Spider-Man survives the impact and faces off with Goblin inside the building, filmed on a Sony soundstage set. John Frazier's team provided physical webs for Goblin's cat-and-mouse pursuit of *Spider-Man* through the ruin, collapsing a wall with a urethane web attachment and stringing up a cat's cradle of web to catch the Goblin between two walls — both effects spun digitally by

Imageworks. ADI also created special versions of the Goblin suit for shots as the encounter grows more physical. “We built a waist-up stunt dummy of Willem Dafoe in his mask,” said Alec Gillis. “This was designed to receive punches, with pieces flying off. Sam wanted it to be like *Raging Bull*, taking all the impacts.” ADI also generated prosthetic cuts and gashes for Tobey Maguire, featured in the fight as a pumpkin bomb blows half of *Spider-Man*’s hood away, dramatically unmasking Parker to the Goblin.

To enhance the impact of the pumpkin bomb explosion, John Dykstra commissioned Hunter/Gratzner to create its final effect for the film — a large-scale version of the bomb that filled frame and exploded with live pyrotechnic detail. Using a mold supplied by the physical effects team, HGI crew chief Jim Waterhouse fabricated a double-size version of the bomb, casting hollow pieces in brittle resin, rigged to explode per instructions from Dykstra. “The great thing about working with John,” observed HGI co-founder Ian Hunter, “is that he is very detail-oriented with pyro. He didn’t want to throw gasoline at a model and blow it up. He wanted it to be an event. His idea was that when the pumpkin bomb blew up, it would have an inner core that would also explode. So we fitted the outside bomb with primer cord and flashbulbs, which disintegrated the surface. Then we loaded the center with more primer cord, jerbs and gasoline, so a split-second later, the inner bomb went off.” Pyrotechnician Richard Stutsman rigged a delay between blasts, and insulated charges to ensure the first explosion did not simultaneously ignite the second; then delineated the charges chemically, to Dykstra’s brief, loading a blue-green outer flash and an orange inner core. Hunter hung the bomb against black above a Mitchell camera to produce a ‘zero gravity’ effect, fire and debris raining out in all directions, then Angulo photographed the explosion at 120 frames per second. Imageworks tracked and matched the detonation to a digitally animated pumpkin bomb that filled frame and ripped into *Spider-Man*’s face.

With Parker’s identity revealed, Green Goblin levels the field by removing his own helmet, stunning Parker with the realization that he has been fighting Norman Osborn, father of his best friend. Forever scheming, Osborn secretly hits a button on his Goblin suit, summoning his glider — armed with vicious spears — which hovers silently on the other side of a thin wall. Unknown to Osborn, Parker has a surprise of his own. “The camera cuts close on Tobey and moves into his eyes,” Scott Stokdyk explained. “We pan and punch through a trellis in a nearby wall — where Peter can’t physically see, but where the glider is hidden — and we see the glider in closeup as its blades come out. We then come back to Peter, who we now know has sensed the threat, using his spider-sense.” Dykstra and Nicholson shot the scene, using Camera Control’s motion control rig, with no trellis and no glider. Imageworks modeled the trellis digitally and tracked it to the scene, allowing the camera to pass impossibly through a chink in the wood, come to rest on the menacing CG glider, then retreat.

Moving with spider speed, Parker darts aside as the Green Goblin launches the glider through the wall, propelling it through a CG trellis, animated to shatter over objects and live geometry in the scene. The glider misses Parker and instead impales the Goblin with its spears, leaving Norman Osborn to expire in a manner reminiscent of the character’s death in *The Amazing Spider-Man* #122.

Parker leaves the site with his secret intact and returns to his double life, now bearing the mantle of a seasoned superhero — gifted but alienated by his extraordinary abilities. As day breaks on another

day in New York City, Parker takes flight, clad in red and blue, and the camera moves with him for a 753-frame grand finale final swing — the most elaborate of Imageworks' visual effects shots in the film.

The final swing incorporated daylit textures of all the major city structures used in the film, as well as footage captured in a live-action location shoot. "Daytime lighting in our city model was a lot more difficult than nighttime," said Scott Stokdyk. "In nighttime scenes, your eye focuses on the highlights and your mind fills in the gaps; but in daylit scenes, surface textures play a much bigger role and all the softness problems are right in your face. That's why we chose to shoot a real piece of city for the final swing. It's only featured in a couple of seconds of the shot, but it helped ground the shot and gave us the correct spacing of the buildings and the correct height variations."

Dykstra staged the live-action shoot for the final swing in downtown Los Angeles, flying a remote-controlled SpyderCam piloted by Earl Wiggins a full city block along Flower Street, riding cables suspended between two cranes. Neil Spisak dressed the location with ground-level detail, including fifty New York City taxicabs and vehicles, and 200 extras dressed in winter attire. The arcing camera trajectory, descending from above tree level to a few feet above ground, zipped between moving taxis at door level, then ascended above tree height again as the basis for the camera point of view from behind *Spider-Man's* head and shoulders as he swung.

Taking the live footage, Imageworks tracked the shot and built it into a 3D previsualization that extended the approach to begin with a more objective virtual view, high up among CG buildings, that followed *Spider-Man* as he entered frame, swinging left to right. Overtaking camera, *Spider-Man* then descended to skim the street, the camera chasing him up and out the other side. "We kept the trees on either side of the real street," said Stokdyk, "then we replaced a number of the buildings, cherry-picking the ones we did and didn't want. In the background to the left of our city plate, for instance, we had a very reflective modern building that reflected the SpyderCam crane, so we replaced that with a CG building. The key was to keep any of the reflective elements consistent with our virtual world."

Peter Giliberti handled animation of the CG *Spider-Man* through-out the final swing, manipulating the character to hit key comic book poses while grappling with the dynamics of the human form traveling through speeds approaching 120 miles per hour. "It was a very extreme dynamic sequence," observed LaMolinara. "We started off by blocking the key poses; but at the apex of the swing, there was not a hell of a lot for him to do but hang on. So we animated him to make adjustments as he swung, concentrating on his forearms, his spine and the muscles in his legs, to make the moves feel natural." The animation process also involved manipulation of virtual camera controls in as much as it involved handling of the character. "We controlled camera shake, both in frequency and amplitude. That really helped us get the feeling of what it would be like for a real camera traveling with the character, with wind buffeting on the flat surfaces of the camera. We were also always trying to use the composition of the frame to convey the full impact of the shot. Whenever *Spider-Man* began to swing into an ascent, we would hold him lower in the frame at first, then let him move from the bottom of the frame to the top, exaggerating the movement and giving it more life. We tried to replicate the mistakes that a camera operator might make trying to hold someone in frame that was moving so erratically, and so fast."

As *Spider-Man* swooped up and out of the live-action location, Stokdyk's team replaced the Los Angeles far distance and vanishing point with a diminishing-perspective 3D view of New York. The camera then swung upwards with the character to take in a fictional Sony Metréon entertainment complex — wry studio product placement patterned after Sony's glass-fronted building in San Francisco. "We took some liberties in the layout of New York," said Stokdyk. "It was a huge mix of real world and CG." Spidey then rappels with a running leap back into a completely virtual domain. The camera spins 360-degrees around the web-slinger, briefly reveals him backlit by the early morning sun in a classic Steve Ditko lotus pose, the teeming street below, then completes its circle to reveal him looping the loop over a construction crane to scale another completely fictional CG building. "The live photography really helped us gauge the camera's motion blur throughout the shots. Other times the background plates helped us judge key-to-fill ratios of sunlight on our virtual buildings, such as with the golden sunlight in the final swing. We added a little more key here and there to break the light up across some of the buildings."

Ascending to the upper level of the fictional building, surrounded by a sky-dome painted from background textures by Ivo Horvat, the camera circumnavigates *Spider-Man* again, taking in a 360-degree view over the tops of the skyscrapers of Manhattan. Modelers constructed an array of 3D structures for the angle, with recognizable glimpses of a CG Chrysler Building and Empire State Building, backed by a digital cyclorama. Adhering to a flagpole with the tips of his toes and fingers, the CG *Spider-Man* is briefly framed against a CG American flag — Old Glory filling frame behind him — before he looks right into camera, metallic eye shields shining, and closes out the film.

First samples of the film's ambitious imagery appeared in Summer 2001, with the release of a teaser poster and teaser trailer featuring Spidey apprehending a helicopter full of bank robbers using a web spun between the twin towers of the World Trade Center. Produced by Propaganda Films, with visual effects supplied by Creo in Santa Monica, the trailer intermingled Imageworks' CG *Spider-Man* and city with Creo shots of a real and CG helicopter, Imageworks' CG web and the real towers. The images took on a different light after the terrorist destruction of the Trade Center threw a tragic pall over the nation, and Columbia responded by removing the teaser poster and trailer from distribution. "The World Trade Center was featured very prominently in the teaser trailer," noted John Dykstra. "That became a point of pain to a lot of people, and that was not the business of this movie, so the studio removed it. However, no changes were made to add or delete the towers from any of the scenes in the film, because they were not featured in any of the scenes."

Dykstra's approach to the visual effects of *Spider-Man* — re-creating large swaths of the film's environment and central characters digitally, to photorealistic degrees — did, however, allow the filmmakers greater creative freedom than anyone had imagined in refining their story. "One of the most important facets of visual effects in contemporary filmmaking is the ability to be flexible," Dykstra emphasized. "It can be maddening, but you have to accept that. Sam was very much a director who, when he began to shoot a sequence, had a set of storyboards and a shot list that he wanted to achieve — and then he improvised as he went along. We had to be ready and willing to come up with new shots at a moment's notice; but it was great because we really got to work in a very collaborative way with Sam."

The task of pulling together the myriad elements to bring *Spider-Man* to the screen ultimately resulted in the production of 444 shots at Imageworks, with visual effects coordinator Lisa Zusmer incorporating contributions of sixty shots by Pixel Magic, sixty shots by Digiscope and thirty by Composite Image Systems. “Our biggest challenge was the fact that we set ourselves up to build so many digital shots from scratch,” remarked Scott Stokdyk. “We had so many virtual sets, and so many CG components, it gave Sam and the producers a great amount of freedom to revise and improve their movie. We strove to preserve that amount of freedom, and respond to any of their needs, without running out of time. Of course, that’s always the aim in visual effects; but typically, on an all-CG movie, you lock into shots very early in production because it takes months and months and months to get them done. On *Spider-Man*, we were changing shots right up until the last minute.”

For Sam Raimi — whose films have ranged from the visceral *Evil Dead* trilogy, to a Capra-esque baseball drama, *For Love of the Game*, and, perhaps most tellingly, an earlier superhero drama *Darkman* — *Spider-Man* represented a culmination of ambitions and an opportunity for the filmmaker to spread his wings. “I had no idea what was possible, digitally, until I made this film,” Raimi confessed. “John Dykstra and the people at Imageworks opened up my mind to those possibilities, and it was a revelation. Now that I know, I am a dangerous fellow!”

Spider-Man photographs copyright © 2002 by Columbia Pictures Industries. All rights reserved. Production still photography by Zade Rosenthal. Additional photos courtesy of Sony Pictures Imageworks, Amalgamated Dynamics, Digiscope and Grant McCune Design. Special thanks to Don Levy, Mary Reardon, Ileen Reich, Denise Balbier, Mia Rehm, Michael Kirk, C. Marie Davis, Victor DiMichina, Kerry Gammill, Jeffrey Tolvin and Tony Ferriter.

Love & War

image

article by Jody Duncan

The roar of publicity surrounding the long-awaited release of *Star Wars Episode I: The Phantom Menace* had just begun to quiet when George Lucas, producer Rick McCallum, a team of concept artists at Skywalker Ranch, and various production department heads from around the world began work on Episode II of the saga – eventually titled *Attack of the Clones*, a moniker conjuring the Saturday matinee serials that had inspired Lucas when he first conceived *Star Wars*.

As early as September 1999, fewer than four months after *The Phantom Menace* stormed thousands of theaters, Lucas began writing his screenplay, later joined by Jonathan Hales, a veteran of Lucas' *Young Indiana Jones Chronicles* television series. At the same time, director of concept design Doug Chiang and his team of artists were developing creatures, environments and hardware in sketches, paintings and models. Production designer Gavin Bocquet and costume designer Trisha Biggar ultimately refined those designs and realized them for the start of filming at the recently built Fox Studios Australia in Sydney, on June 26, 2000 – three years to the day after filming had begun on *The Phantom Menace*.

Production spent two months on the Fox stages, then moved to locations in Italy, Spain and Tunisia – notably, returning to location sites featured in the original *Star Wars* – and completed filming at Elstree Studios in England. Though the production schedule was much like that for *The Phantom Menace* in terms of number of days and Lucas' legendary breakneck pace, the *Attack of the Clones* shoot distinguished itself in one very important way: it was the first time a full-length, large-scale motion picture was shot entirely on high-definition digital video, rather than on film.

Lucas, who had tested the high-def waters on *The Phantom Menace* with a handful of digital video shots, was convinced that the format's clarity, efficiency, cost-savings and compatibility with digital effects production made it the wave of the future. Just as he had so often in the realm of digital effects technology, Lucas placed himself firmly in the forefront of the high-def movement by initiating the development of a digital camera for film application in 1996, a full year before the start of production on *The Phantom Menace*.

Many within the film industry expressed doubts about the high-def approach, citing both aesthetic and technical concerns. Some directors of photography argued that high-definition digital video would never produce as rich and textured an image as film, precisely *because* of its clarity, its lack of grain and other imperfections. Technical hurdles were more concrete and included a frame-rate incompatibility issue: digital video cameras typically ran at the broadcast standard of 30, 50 or 60 fields per second, while film projectors were geared for the film rate of 24 frames per second.

Ever the pragmatist, Lucas rejected the aesthetic objections of film purists out of hand, while facing the technical problems head-on, working with Sony Engineering in Japan to develop a new high-def digital camera in time for the start of production on *Attack of the Clones*. High-definition supervisor Fred Meyers, working out of ILM, acted as technical liaison with Sony and other vendors.

The first hurdle was overcoming the apathy of leading HD digital camera manufacturers, none of which were convinced that a new, 24-frames-per-second camera was a necessity. “At first,” said Meyers, “Sony and other HD camera manufacturers thought the best way to go would be to use the available cameras and *adapt* a broadcast standard to a film project. But the extra work a filmmaker would have to do to make that broadcast standard work for film was impractical, which we realized after some painful tests. So we had to convince the manufacturers to come up with something at 24 frames per second and make it work. Once they agreed to that, it opened up the doors to the new camera.”

Panavision became involved in the project by agreeing to build two zoom lenses to work in conjunction with the new cameras. “There are accessories for cameras that have been developed over a period of many years and that film crews are accustomed to working with,” Meyers noted. “If we were going to take a film camera away from the DP and the camera operator and replace it with this digital camera, it was essential that we give them accessories they were familiar with. A DP would have to be able to use the same type of filter he’d have used on a film camera; he’d have to be able to remotely control the focus of a lens just like he would on a film camera. Everything in the camera package was designed and built with the DP and the cameraman in mind.”

The first six prototype cameras were up and running by Day 1 of principal photography, and performed beyond everyone’s expectations throughout. The digital cameras, which did not require reloading, enabled Lucas – always a fast-paced director – to shoot even more quickly, often as many as thirty setups per day.

Upon returning to Skywalker Ranch, Lucas and editor Ben Burtt cut the digital live-action material with animatics that had been produced by animatics supervisor David Dozoretz and his small crew during the nine-month production ramp-up. Work on the animatics continued well into filming, resulting in rough 3D versions of nearly every effects shot in the movie – effects that would be realized by Industrial Light & Magic.

To represent ILM’s interests on the set, visual effects supervisor John Knoll – along with matchmove lead Jason Snell – had accompanied the production in Sydney and on location, returning to begin the effects effort in earnest that fall. The 2000-shot show – the size of three large-scale productions – was divided among three in-house units: one serving under Knoll, another serving under Pablo Helman, and yet another working under the joint leadership of Dennis Muren and Ben Snow. Though Muren was instrumental in setting up his unit and made himself available on a consulting basis, he ultimately left Snow in charge as he segued into supervisory duties on Ang Lee’s *The Hulk*.

Executive visual effects producer Judith Weaver orchestrated coordination between the three units, while visual effects producers Jill Brooks, Gretchen Libby and Heather Macdonald worked with the Knoll, Helman and Muren/Snow units, respectively. Inter-unit collaboration was encouraged with every-Monday dailies in which shots-in-progress would be reviewed by members of all three crews. “We also had a lunch every Tuesday,” said Weaver, “with all



Political turmoil only hinted at in *The Phantom Menace* severely taxes the peacekeeping resources of the Jedi Order ten years later in *Attack of the Clones* – the latest episode

the supervisors and the producers from each unit, along with animation director Rob Coleman and research and development CG supervisor Dan Goldman. We'd talk about the show and exchange ideas. It reminded us all that we were working together – each unit could not be a discrete piece. What one unit did affected the others.” The stage photography crew, which shot miniatures, various bluescreen and greenscreen elements and pyrotechnics, floated between all three units, as did Rob Coleman’s group of animators, the model builders – both CG and practical – and the viewpoint artists.

in the Star Wars saga. As the story opens, the Republic is plagued with an escalating secessionist movement, contention within the Senate over the employment of military force, and a series of assassination attempts against Padmé Amidala, former queen and current senator of Naboo. Within the hallowed halls of the Jedi temple, masters Yoda, Obi-Wan Kenobi and Mace Windu discuss the intergalactic chaos and the growing power of the dark side.

Attack of the Clones picks up ten years after the events of Episode I. The adolescent Queen Padmé Amidala (Natalie Portman) is now a 24-year-old senator from her native Naboo, and is at the center of galactic turmoil as the Republic tries to stem the rise of a secessionist movement led by an ex-Jedi named Count Dooku (Christopher Lee). The growing unrest in the galaxy is taxing the peacekeeping resources of the Jedi Order and has led to the proposed creation of a Republic army – an aggressive, hostile measure to which Amidala is passionately opposed. Repeated attempts on the young senator’s life suggest that her opposition is resented in some quarters.

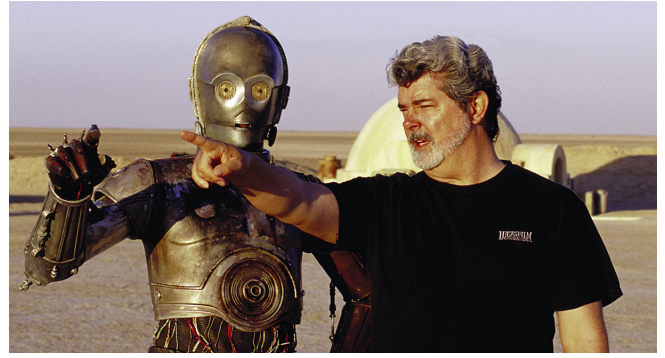
Fearing for her safety, Chancellor Palpatine (Ian McDiarmid) and the Jedi council assign Master Obi-Wan Kenobi (Ewan McGregor) and his 19-year-old apprentice Anakin Skywalker (Hayden Christensen) to act as Padmé’s bodyguards and to learn who is behind the assassination attempts. Thrown together again, and despite their resistance, Padmé and Anakin fall in love – a love that is tested by Padmé’s official responsibilities, Anakin’s Jedi vows and the outbreak of war.

In the movie’s opening shot, a Naboo cruiser and two escorting yellow starfighters descend through dense fog into the Republic capital of Coruscant, a vast cityscape made up entirely of digital matte paintings. Overall, the matte painting assignment for *Attack of the Clones* was double that for *The Phantom Menace*, and required a fourteen-member digimatte department led by Yusei Uesugi, Paul Huston and Jonathan Harb. In addition to the digital matte views of Coruscant, rendered by Uesugi, the opening shot featured airborne traffic and the Naboo starships, all of which were created by ILM’s ‘rebel unit,’ a small, long-established, Macintosh-based group operating outside the main CG pipeline, which works in packages such as Adobe Photoshop, Adobe AfterEffects, FormZ, Electric Image and LightWave. The rebel unit also assembled the shot, creating the misty atmosphere with computer generated fog and matte-painted clouds applied to cards to facilitate a multiplane, 3D camera move. The rebel unit’s Louis Katz replicated and digitally extended a live-action landing platform set, and director of effects photography Marty Rosenberg shot bluescreen elements of masked and costumed performers to increase the number of dignitaries on the platform.

The ongoing threat to Senator Amidala's life is evident when, just moments after her entourage and her double, Cordé, emerge, the royal cruiser explodes. The ship was built in CG by the hard-surface modeling team, headed by Russell Paul, which worked in Alias Studio, Maya and Softimage. The explosion of the ship – which would be accomplished by running the computer model through a force simulation – was set up by visual effects art director Alex Jaeger. "I laid a color-coded map over the form of the CG ship," explained Jaeger. "When the force simulation was run on the model, certain colored areas would blow off more easily than alternately-colored areas. The map was based on the real physics of an explosion: the tips and cones would fly off more easily than the main body of the ship." Also composited into the scene were practical pyro elements and rendered particles to create fiery debris.

The action cuts from the ship explosion and its aftermath to an establishing shot of the Senate building – a matte painting combined with foreground statue miniatures, approximately two-and-a-half feet tall. The array of statues represented just one of the movie's more than 100 model setups. Modelshop supervisor Brian Gernand and his crew, which numbered 80 at the height of production, relied on the 3D animatics from the Ranch to determine how much of each set would be built in miniature. "The animatics were essentially final shots," Gernand observed, "at least in terms of composition and camera movement. They told us how any given set would really play in the shot and, consequently, how much we needed to build. In the past, the tendency has been to build more than what we needed, just in case, which costs time and money. This time, we were able to build no more, no less than what we actually needed for the shots." Another benefit to the animatics was that their files could be transferred into 2D AutoCAD or 3D Rhino files, to guide the laser-cutting of model pieces.

Early in the project, there was uncertainty as to whether miniatures would be shot on film or on HD; but as Lucas' confidence in the HD cameras grew, he opted to use them for both live-action and effects photography. The increased fidelity of the high-definition image added a wrinkle to the standard model-building process. "We had to do a lot of things in building the miniatures that were different from what we normally do, because of the HD," said Gernand. "With film, you get grain and blurring, which help to make miniatures impressionistic-



After two months at Fox Studios Australia, director George Lucas moved cast and crew to various international locations, including Tunisia, where iconic settings such as Luke Skywalker's moisture farm homestead on Tatooine had been erected for the original Star Wars. Returning to the desolate Chott El Jerid salt flats where those homestead sets had stood twenty-four years before, the production replicated the igloo-style structures on precisely the same spot. Lucas directs Anthony Daniels as protocol droid C-3PO on location.



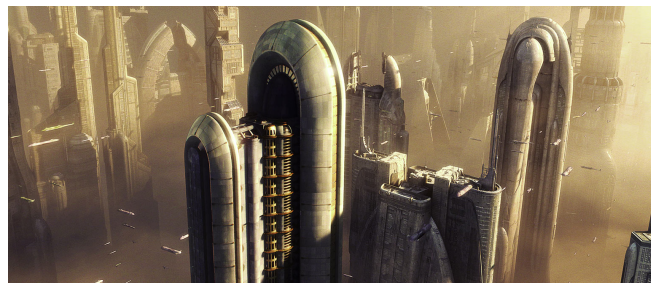
looking. Film obscures some of the imperfections of a miniature. But in high-definition, there was no impression – you saw every sharp line and hard edge. We literally had to change how we looked at the models. Normally, we'd squint our eyes, which gave us a pretty good idea of what the miniature would look like on film. With HD, whatever it looked like on the stage, right in front of us, with our eyes wide open, that's how it was going to look on the screen." The sharpness of the image meant that standard aging techniques, for example – such as squirting water and paint onto a model – would not suffice. "For a film project, we never had to do much to hide that technique, because we knew those runs of water and paint were going to soften a bit. But with HD, that technique looked like paint and water squirted on a model. So we did a lot of meticulous hand-painting to make the aging look realistic."

The model photography crews, too, had to adjust their decades-old methodologies to accommodate the high-definition video. Typically, depth of field on a miniature would be created by stopping down the lens and increasing the exposure time per frame and/or throwing additional light on the subject. But the new HD cameras could only run at 24 frames per second. "That meant we had to come up with different approaches to deal with the depth of field problem," said director of effects photography Pat Sweeney. "We either had to add a lot more light to our model setups to create depth of field, or we had to shoot them in separate focal planes – essentially dividing each shot into close focus, medium focus and far-away focus, shooting each one separately, and then combining them."

Another problem in shooting everything at 24 frames per second was that the crews could not move their camera dollies and cranes fast enough to do very fine moves on the miniature sets. "We couldn't move the motion control camera through the set at 24 frames per second," said Sweeney, "because, at that rate, it would be shaking too much. So we ended up moving the camera on the crane at a reasonable pace – typically 1 to 6 frames per second. But because the camera was running at 24 frames per second and the crane was running slower than that, we wound up with a lot of extra footage. So, in post, they pulled out the right number of frames."

The technique was called 'frame merging.' "We deleted frames," explained director of effects photography Carl Miller, "and then we merged the remaining frames together. The digitally captured images contain numbers, which range between 64 and 1019: 64 is black, and 1019 is white. So, to merge the frames and get motion blur, we added all the numbers together from each of these frames, then divided by the number of frames; and that enabled us to create one frame. The more frames we added on top of each other, the more we got what looked like motion blur. Merging is what allowed us to use these HD cameras at all for motion control shots.

The first published photograph of the match the included today, called The Empire Strikes Back. Astronomer of the world's efforts to the physical effects of the film. Logical Malignant High School's supervisor Geoff Campbell and the hand-painted model by Robby Gibb expressiveness followed for the head production of more facile computer animated behavior.



Early in the story, Obi-Wan Kenobi and his nineteen-year-old apprentice, Anakin Skywalker, are sent to protect Senator Amidala at her official residence on Coruscant, the Republic capital. For establishing shots of the executive apartment building, the edifice was built as a 1/48-scale miniature by modelshop supervisor Brian Gernand and his crew, which ultimately provided more than one hundred models for the production. Digital matte

And it allowed us, in some cases, to get improved depth of field on a miniature, shooting it all at once, rather than having to separate it out.”

paintings of fancifully stylized skyscrapers, enhanced with CG airborne traffic, filled out the expansive frame.

Despite its pitfalls, the high-definition camera brought great benefits to the visual effects photography, such as the ability to shoot up to four times faster than with a film camera, resulting in the stage crews averaging three to four shots per day, as opposed to the standard shot every day or two. “We didn’t have to do wedges anymore,” stated Miller. “We could instantly see what we shot, and determine if it was right or not. We didn’t have to wait overnight for dailies to be processed. We could just grab the tape and walk over to dailies, get it approved, then rip the set down and start building the next shot.”

Inside the Senate building, in the office of Chancellor Palpatine, galactic delegates and members of the Jedi council assemble to discuss the assassination attempts against Padmé. The office was a full-size set, extended digitally and finished off by Wei Zheng with 3D matte paintings and moving CG traffic elements composited into the set’s large blue-covered windows. Live-action included masked aliens, handled throughout the show by live-action creature effects supervisor Jason Baird and his Queensland-based JMB FX Studio.

The budget-conscious production had determined that, rather than build many new characters, they would rely heavily on the creature masks built by Nick Dudman for *The Phantom Menace*. The plan worked for Baird, as well, since he was brought onboard just five weeks prior to filming, leaving little time for new construction. Baird and his crew organized all the existing creature components and molds to determine what new construction would be required, then began running foam appliances and prepainting prosthetics, a process that would continue throughout principal photography.

Also inserted into the live-action office set were additional masked performers not present during the stage shoot – filmed bluescreen at ILM – and CG characters, such as Jedi Master Yoda. Except for a lone long-distance CG Yoda shot in *The Phantom Menace*, Yoda had always been achieved through puppetry, which, despite the brilliance of Yoda performer Frank Oz, had inevitably resulted in a physically limited character. That changed with *Attack of the Clones*, which would feature an all-CG Yoda throughout.

The animation of Yoda and all the computer generated characters was the domain of animation director Rob Coleman, who oversaw a team of up to sixty animators, charged with churning out an ambitious seventy minutes of animation for the film – ten more than that featured in *The Phantom Menace*.

Lucas had considered employing a digital Yoda for *The Phantom Menace*, but he had held back due to the tremendous volume of work ILM was already tackling for that film. Two months before the start of principal photography for *Attack of the Clones*, Lucas approached Coleman and John Knoll, asking if it



would be feasible to do an all-CG Yoda for Episode II. Coleman, who had been an advocate of the digital Yoda for *The Phantom Menace*, was fully behind the idea. “Being able to do a digital Yoda was the reason I did this movie,” Coleman asserted. “The challenge was not only to sell it to George and make him happy with it, but to make the fans happy with it. I knew I was treading on holy ground by even attempting to do a CG Yoda, because everyone loved the puppet so much and because Yoda is, arguably, the most important character in the whole Star Wars saga.”

Modelmakers Loren Hillman-Morgan and Lauren Vogt detail the apartment building miniature, the middle section of which was digitally cloned as a means of realizing a structure hundreds of stories tall in the final shots. Because the movie was shot entirely on high-definition video, decades-old modelmaking techniques – which relied on film grain and blur to hide a multitude of sins – had to be rethought and revised. Aging of the miniatures – formerly a simple matter – now required meticulous hand-painting and detailing.

To convince Lucas that the beloved puppet could be replicated exactly in CG, Coleman produced a series of test shots. For reference in the building and animating of a Yoda computer model, Coleman and digital model supervisor Geoff Campbell studied footage from *The Empire Strikes Back* and *Return of the Jedi* rather than archived Yoda puppets, all of which were too fragile to be handled. “The only thing we had physically in front of us was the puppet from *The Phantom Menace*,” Coleman stated, “which I felt was too different from the Yoda in *Empire Strikes Back* to use for reference. So we pulled some frames out of *Empire Strikes Back* and *Return of the Jedi*. After studying those, we could see there were actually four distinctive Yoda puppets that were used. There was what I called the ‘fat lip’ Yoda, for example, and a slightly cross-eyed Yoda. I don’t think fans ever noticed that; but we picked up on it because we were studying the minutiae of what it is to be Yoda.”

Campbell also scanned an eight-inch-tall Yoda head maquette, produced by the Ranch art department; but this maquette, like the puppets from Episode I, did not look enough like the Yoda of *The Empire Strikes Back*. “He looked too young,” Campbell commented, “and his head was a bit too round. So we continued to revise the model, getting it to look more and more like the Yoda of *Empire Strikes Back*.”

Once the look had been pinned down, lead creature developer Lenny Lee defined the anatomical behavior of Yoda’s skin, creating a naturalistic stretching and compressing by weighting Yoda’s face to the various moving joints of the head, such as the jaw, neck and tongue. Additional rigs were added to the neck to accommodate more realistic movements of the mastoid muscles and throat. Geoff Campbell then created a facial library of expressions. Throughout production, Campbell’s team used in-house modeling tools such as Caricature and I-sculpt, as well as Maya, Softimage and Alias for the building of their computer models.

The Yoda model then passed through the viewpaint department where, again, the look of the character from *The Empire Strikes Back* served as inspiration. To give the computer model the rubbery texture of the puppet, research and development technical director Christophe Hery developed a number of shaders, further refined by technical director Alan Rosenfeld and look development technical director John Walker. “It wasn’t that difficult to make the model look rubbery,” noted viewpaint supervisor Jean Bolte. “The hard part was to restrain ourselves from making the skin look translucent and too real. We had to create a non-translucent look, because that’s what Yoda had always looked like.”

For the test, Coleman and his team animated the revamped Yoda model, reproducing three shots from *The Empire Strikes Back*. Developing the CG Yoda body animation was a matter of distilling the puppet movements in the previous films down to their most basic characteristics, then reverse-engineering the digital performance. “We could see what Frank Oz was doing with the walk in the old footage,” Coleman explained, “but then we had to figure out what would really be happening with the legs to make that walk. We found that if we just took the head bobs of the puppet walking through his little house in Dagobah, it was very difficult to make the feet and legs look like they were really producing that bobbing movement. So animator Linda Bel created a new walk that was a bit different – but Yoda still bobbed, still labored as he walked, still put a lot of weight on his cane, still did all the things the puppet had done.”

Similarly, the physical limitations of the puppet’s face had to be incorporated into the digital facial animation. To better understand the puppet’s mechanics, Coleman observed Frank Oz as he articulated the Yoda puppet face with his hand. “Once I looked at the old Yoda shots again with that in mind,” Coleman stated, “it helped me to direct the animation of his face. The mouth on the Yoda puppet didn’t articulate much, because it only had up-and-down movement. He couldn’t form vowels and phonemes and look like he was really talking – but everybody thought he did! Even people who had watched *The Empire Strikes Back* over and over again thought that puppet was doing more than it was. Even I had a flawed memory of what I thought I saw in 1980.”

The degree to which viewers had ‘filled in’ lip-sync articulation that was never present in the original puppet became clear to Coleman when, as an experiment, he instructed his animators to animate the mouth of the CG Yoda exactly as it appeared in *The Empire Strikes Back*. “I showed that version to the animators,” recalled Coleman, “and they all said, ‘It doesn’t look like Yoda!’ – even though it was a perfect match of the puppet’s movements. So then we started to put a bit more articulation in the face, in the mouth, in the eyes; and all of a sudden, he came alive. We were always dancing that line between animating Yoda to look like he had originally, but pushing it a bit so that it matched what people remembered. Early on, Frank Oz had warned me, ‘You guys have too



When bounty hunter Zam Wesell attempts to kill Padmé in the senator’s apartment, Anakin – with a nervous Obi-Wan beside him – aggressively pursues the would-be assassin, racing through the airways of Coruscant in a souped-up airspeeder that recalls the hot-rods of Lucas’ *American Graffiti*. Live-action elements of actors Ewan McGregor and Hayden Christensen – captured on a cockpit set mounted to a custom gimbal for extreme rolling and banking maneuvers – were composited with CG speeder exteriors and digital backgrounds rushing past at high speeds.



To create a sense of the speeder chase progressing through many different areas of the city, visual effects supervisor John Knoll and his team produced a number of distinctive environments, either digitally or through miniatures. The chase starts in the upscale and ultra-modern ‘heights,’ where Padmé’s residence is located, moves through an older, gothic part of town, passes through a financial district and an industrial area, and finally ends in a Las Vegas-style entertainment area. All of the chase action was first choreographed in animatics created at Skywalker Ranch.

much potential' – meaning we could do things with a digital Yoda that Frank could never do. Obviously, with a digital character we could do whatever we wanted. The question was, how much should we do."

Ultimately, the animators found that balance. They were, in fact, so successful in re-creating and building upon the puppet Yoda performance that Frank Oz was moved to write a letter of thanks and congratulations to Coleman after seeing the final CG Yoda shots. "Frank Oz had established something so magical and special with the puppet," Coleman admitted, "it was very important to me that I not do a disservice to that with the CG Yoda. It was my biggest worry; but Frank's letter certainly helped ease my sleepless nights."

Beyond the artistic concerns of gracefully segueing from a puppet Yoda to a digital one were the technical challenges of simulating the character's hair and clothing. The cloth simulation that ILM had developed for *The Phantom Menace* was insufficient for *Attack of the Clones*, which, in addition to the prominently featured Yoda, would require digital doubles for all the leading characters and an ornately-dressed Jar Jar Binks. An intensive R&D effort, overseen by CG supervisor Dan Goldman, was put into upgrading the cloth simulation. "We had a number of CG characters that were going to be seen full-frame," Goldman stated, "and our cloth simulation couldn't produce that level of detail. So research and development leads Sebastian Marino and John Anderson, along with CG software engineer Ari Rapkin, rewrote the software to improve the cloth simulation engine."

Among the upgrades was a reworked collision model, which would simulate the movement of the character's body beneath the clothing, and translate that movement appropriately to the cloth. For Episode I, all of the deformations in the geometry of a given character model had been used as the collision object; but that method had proven unwieldy and unnecessarily detailed. "Most of the cloth for this show was going to involve heavy robes," Goldman commented, "where you wouldn't see the definition of musculature and all of those deformations underneath anyway. So instead of colliding against an exact match of the surface of the character, we used loose shapes that represented the body beneath the cloth. The cloth would collide against these gross, simplified shapes, rather than the fully detailed high-rez model. It was a much more compact way of doing it – which meant problems could be solved more easily."

Technical animation supervisor James Tooley oversaw the application of the improved cloth simulation, defining what kind of fabric a particular piece of clothing was made out of, how much it would wrinkle and what it was going to collide against. "We also determined fluid dynamic parameters," Tooley said, "which would dictate how much the cloth moved in the wind, and in what direction. Other parameters determined how different parts of a garment would behave in the wind – some parts might be stiffer than others, and would therefore behave differently. All these parameters were put into the main physics of the cloth engine. Then, a few painted elements guided subsections of the garment and how they behaved – where things were stiffer, for example, we painted a band of stiffness around it. In some cases, we actually tacked a piece of the garment onto the body of the model – as if we were using spirit gum on a real piece of cloth – to keep the cloth from slipping off or sliding." In total, the film featured 360 cloth shots, 125 of which involved Yoda. Thirty-one of the film's CG characters wore some form of clothing.

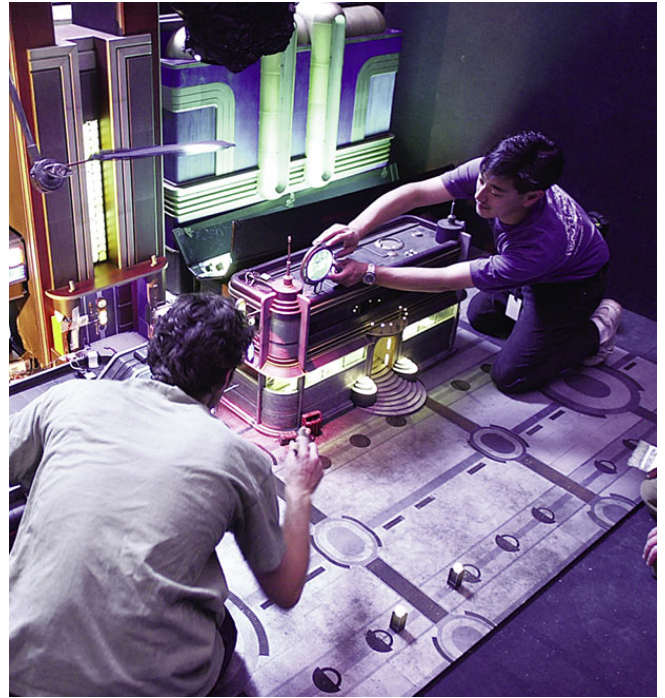
A related simulation was required for Yoda's hair, digital doubles' hair and other furry CG characters. "Yoda's hair used what we called guide strips," observed Tooley. "We'd create a few of these guide strips, and then the TDs would interpolate those to create a full tuft of hair on his head."

Pablo Helman's team, responsible for the integration of ninety percent of the Yoda shots, found that Lucas was extremely particular about the look of the character's hair. "Yoda's hair really bothered George," recalled Helman. "He'd look at a shot, and say: 'No, no, no. You need to go back and look at Yoda's hair in Episode I or Episode V' – but when we did, we discovered that Yoda's hair was all over the place in those films! It was uncombed, and it looked different from one shot to the next."

"In some shots," added Helman unit CG supervisor Robert Marinic, "depending on the angle we were seeing him from, Yoda looked like he had a serious case of bed-head."

After some trial and error, Helman's team began to understand that what Lucas wanted was a more combed look to Yoda's hair. As if readying a child for a family portrait, the digital artists would attend to Yoda's grooming as a last step before presenting final shots to Lucas. "Before we'd show a Yoda shot to George," said Helman, "we'd always comb his hair."

Another CG character reintroduced in Palpatine's office is Jar Jar Binks, now a senator from Naboo. Early on, Lucas had entertained the idea of changing Jar Jar's demeanor, making him a more dignified, well-spoken character as a result of his ten years in the Senate. The animators had begun to produce shots of this new Jar Jar when Lucas nixed idea, mainly because he could not spare the screen time to explain such a transformation. "When I showed George those performance shots of Jar Jar," related Rob Coleman, "he said: 'What's the matter with Jar Jar? He looks stoned.' I said: 'Uh, no, he's being regal – that's regal.' And he said: 'That's all wrong. That's not Jar Jar.' So we went back to the old Jar Jar to some extent, but not completely. He is more regal in this movie, especially in his first scene in the chancellor's office, where he is just standing



When Zam's speeder crashes in the entertainment district, Obi-Wan and Anakin continue the chase on foot. A minimal full-size street set on the Fox stages was augmented considerably with miniature buildings, repositioned and redressed to accommodate more than a dozen model setups. Modelmakers Aaron Haye and Grant Imahara finalize one of the street sets.



Modelmaker Peggy Hrastar adds airbrush detail to a larger-scaled miniature that stood in for the exterior entrance of the sports bar where Zam Wesell hides from her Jedi pursuers.

there. Later, when he speaks, he is the Jar Jar we all know and love, flopping around all over the place.”

Geoff Campbell made subtle alterations to the original Jar Jar model from *The Phantom Menace*, making him appear a bit older by giving him a jowly neck, and a heavier, puffed-up face. “No one was really consistent about using those aging shapes,” said Campbell, “so in some shots Jar Jar looks younger than in others. After awhile, we decided that the paint alone could get that effect, because he hasn’t aged that much.”

Jar Jar’s diaphanous, ceremonial robes – modeled by Michael Koperwas and painted by Scott Bonnenfant – presented headaches for the cloth simulation team. “Trisha Biggar had created some very intricate costumes for Jar Jar,” recalled Coleman, “which Ahmed Best, the voice of Jar Jar, wore on the set, so we could get lighting reference. There was one costume in particular that had little fringes on it. James Tooley spent four months working on the cloth simulation for that, just trying to get those fringes to move and show up properly on the digital costume.”

Agreeing that additional security is needed for Padmé, Palpatine and the Jedi council summon Obi-Wan and Anakin to her side. For an establishing shot of the executive building housing Padmé’s apartment, a 1/48-scale miniature was shot and cloned to create the multi-storied structure. “Because in some of the shots you can see the interior in the windows,” said Brian Gernand, “we also had to match the interior set they’d shot on stage. So we had little scaled furniture in the miniature – everything they had on the set.” A Yusei Uesugi matte painting served as background to the model photography.

In a following shot, Anakin and Obi-Wan can be seen within a glass-encased elevator ascending the exterior of the building. The camera then cuts to the elevator interior, facing Obi-Wan and Anakin, with descending Coruscant structures visible in the glass. Bluescreen elements of the characters, shot in London, were surrounded by Uesugi’s digital matte views. “That view outside the elevator was a killer for me,” remarked Uesugi, “because it is a really long scene between Anakin and Obi-Wan, and I had to cover a 180-degree environment throughout the whole thing.” Ingenuity was called for, as Uesugi had only a limited number of CG buildings available to him, many of which had been seen in Episode I or would be used in other Coruscant scenes in the current movie. “I had to come up with new, fresh-looking compositions, while recycling the same structures.” To produce the effect of sunlight hitting the elevator intermittently as it rose, a fan had been mounted in front of a key light on the bluescreen stage in London, casting flickering light onto the actors’ faces. Grady Cofer – a lead in ILM’s Sabre high-speed compositing unit – composited Uesugi’s imagery with the bluescreen elements of the actors, adding subtle reflections on the elevator glass.

The action picks up at Padmé’s executive residence. Gavin Bocquet’s stage set for the apartment interior was completed with Uesugi’s digital matte paintings of the Coruscant skyline, inserted into massive bluescreen-covered windows. “Those views were all matte paintings, with traffic moving through them,” said John Knoll. “We tackled that by making one very large, high-resolution matte painting, so we could extract all of the different views we needed throughout the sequence.”

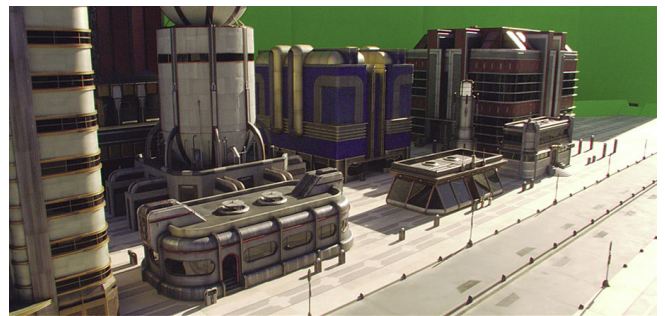
“We did three versions of that matte painting,” added Jill Brooks, “one for daytime, one for nighttime, and one at sunset, because there were scenes that took place in Padmé’s apartment at all three times of day.”

Later that night, as Padmé prepares for bed, the film cuts to a meeting between bounty hunters Jango Fett (Temuera Morrison) and Zam Wesell (Leeanna Walsman) on a skyscraper ledge that was part miniature, part set piece surrounded by bluescreen. Alex Jaeger produced blue-pencil sketches of the buildings adjacent to and behind the ledge, which were later rendered as digital matte paintings or CG sets. “We added a matte painting of the rest of the apartment building exterior and the Coruscant background in shots looking toward Jango,” explained John Knoll, “and when the shot was looking toward Zam, we used 3D computer graphics sets.” The reason for the two different approaches was logistical: the balcony sequence was tackled early in production, before the entire Coruscant cityscape had been built in 3D, whereas the Coruscant skyline matte painting *had* already been generated for the view outside Padmé’s apartment windows. “We wanted to see if we could get away with using that background cyc matte painting to do at least one direction of the balcony scene, so we could get those shots underway. We picked that direction for the matte painting view because it was only in four or five shots.”

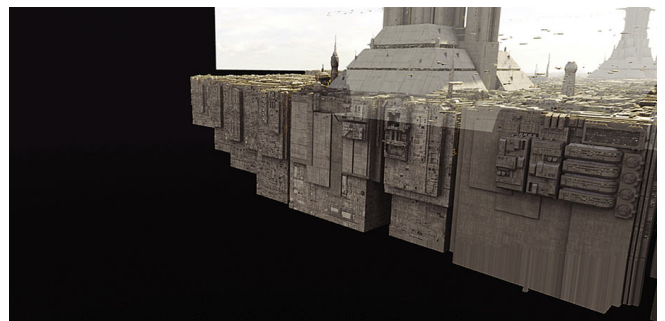
While the actors performed medium and close shots, wide shots of the balcony featured Jango and Zam digital doubles. The armored and helmeted digital double for Jango was the first project taken on by the hard-surface modeling team. “Jango Fett was a mix of creature and hard-surface modeling,” observed Russell Paul. “I did all the armor plating – his guns, his helmet, his chest plates, his codpiece – and Frank Gravatt of the creature model team did his clothing.”

Digital doubles for all the leading characters were employed as a means of realizing fantastic stunt scenes, without time-consuming, potentially dangerous and limiting stunt setups. “George felt that working with live stunt performers forced an artificial editing style and cinematography style,” John Knoll elaborated. “He felt that if you could actually do a stunt in one piece, live, you would shoot it very differently and cut it very differently than what you do when it is done in pieces. So he said up front that he wanted to create digital doubles that would let us generate shots like that. He could shoot them the way he wanted to shoot them, not the way he was forced to shoot them because of the limitations of stunt work.”

Digital doubles started with data derived from head scans of the actors captured in Australia by Gentle Giant Studios. The cyberdata was cleaned up and sharpened by the modeling crew, especially around the eyes. “Because we have eyelashes,” said Geoff Campbell, “a head scan loses a lot of detail around that area. So we spent a lot of time just re-creating the eyes and lips and other details.” The modelers



After Zam is slain by a mysterious toxic dart, Obi-Wan pays a visit to diner proprietor Dexter Jettster, hoping his well-traveled friend will recognize the lethal artifact and its origin. An aerial push-in on the diner to establish the scene featured mid- and foreground miniatures, shot motion control, and a background digital matte painting. Characters walking the street outside were bluescreen elements of ILM staff members in costume and masks.



After Zam is slain by a mysterious toxic dart, Obi-Wan pays a visit to diner proprietor Dexter Jettster, hoping his

built digital double bodies from scratch, using photographic reference of the actors.

New shaders developed by Christophe Hery simulated natural-looking flesh tones. Those shaders, along with the improved cloth simulation, paid off handsomely when, as postproduction progressed, Lucas moved his camera closer and closer to the digital doubles. “George wound up wanting digital doubles much bigger in frame than we had anticipated,” recalled Pablo Helman, “from about the waist up, in some shots. It was difficult, but it was also very exciting, because creating convincing digital doubles was something that everyone at ILM had been striving towards.”

Padmé retires for the night, leaving Obi-Wan and Anakin to keep watch outside her bedroom, further secured with a grid of security beams, achieved by means of straightforward animation. Later that night, a probe droid – a hard-surface CG model – appears at her bedroom window, cutting the glass and releasing two vicious centipede-like kouhuns, small enough to crawl beneath the security grid. The CG kouhuns were modeled by Geoff Campbell, then animated procedurally. “The kouhuns couldn’t be animated conventionally,” stated John Knoll, “because they had too many legs. So we took a very technical, procedural approach to the animation. Keiji Yamaguchi worked out the basic mechanism, then Pat

Myers, our CG supervisor, refined it and did the final animation in Maya.” Because the six kouhun shots came up early in the production schedule, before the visual effects crew had ramped up to its full complement of personnel, Myers not only animated the creatures, he also served as TD and compositor, lighting them and compositing them into the live-action plates.

As Anakin slices the kouhuns with his lightsaber, Obi-Wan crashes through the window to grab hold of the escaping probe droid, which subsequently flies him through the skies over Coruscant. Anakin follows in a speeder, rescuing Obi-Wan and tracking Zam in a high-speed chase. Hard-surface modelers built speeders for Zam and Anakin, designed to resemble fifties-era hotrods, from maquettes supplied by the Ranch. Animation for the speeders and other ships relied on a flight system developed for *Pearl Harbor*. “It was basically just path animation,” said James Tooley, “but it had parameters for speed, and a lot of bells and whistles to articulate flaps and ailerons and that sort of thing.” Scott Benza and Paul Kavanagh animated the speeders and other ships featured in the film.

The hard-surface modelers, in addition to building the speeders, also built CG environments seen as the speeders race through different areas of the city. “George wanted a lot of variety in the cityscapes,” observed John Knoll. “If you drove for fifteen minutes through Manhattan, you wouldn’t see the same types of buildings again and again. There would be a lot of variety. George wanted the same thing for the speeder chase.” Alex Jaeger and a small art department crew worked out the speeders’ path, acting as virtual city planners and creating blueprints of the city’s various sections.

The chase sequence, supervised by Craig Hammack, starts in the ‘heights,’ conceived as an upscale neighborhood. “As the chase continues,” explained Knoll, “we get down into the older parts of the city, with gothic-looking buildings, which had a different color palette and architectural style. Then

well-traveled friend will recognize the lethal artifact and its origin. After Zam is slain by a mysterious toxic dart, Obi-Wan pays a visit to diner proprietor Dexter Flettster, hoping his scene-traveled friend will recognize the lethal artifact and its origin. An aerial push-in on the diner to establish the scene featured mid- and foreground miniatures, shot motion control, and a background digital matte painting. Characters walking the street outside were bluescreen elements of ILM staff members in costume and masks. motion control, and a background digital matte painting. Characters walking the street outside were bluescreen elements of ILM staff members in costume and masks.

the chase passes through an industrial area – built as a practical model – and into the financial district, from the financial district into the warehouse area, and finally into an entertainment street, also built in miniature. Each one of those areas had its own set of CG or practical models that we built, its own look, its own lighting and colors, to make it feel as if there was a progression as the chase went on.” To maximize resources, modelers built a limited number of 3D models, which could be made to look like different buildings by mixing and matching rooftops and other structural details.

To capture medium and close shots of characters within the speeder cockpits, the actors had been filmed on mockups mounted to a blue-covered gimbal built by special effects supervisor Dave Young in Sydney. Powered by a very large electric motor, the gimbal could execute a 190-degree roll, up to 25 degrees of pitch, 60 degrees of yaw, and could snap-roll from a vertical position to an upside-down position in less than two seconds – all while traveling down a track. The gimbal movements were so dynamic, in fact, that Ewan McGregor and Hayden Christensen, who spent the most time on the rig, often experienced the kind of wooziness brought on by repeated thrill-ride excursions. The gimbal, in addition to being flexible and powerful, was portable, and could be moved from stage to stage as needed.

What guided the filming of the actors on the gimbaled mockups, backed by bluescreen, were chase sequence animatics consisting of David Dozoretz’s 3D images and aerial and car chase photography from other films, cut together by editor Ben Burtt. The animatics were played on monitors in front of the actors in the speeder mockups, allowing them to see exactly what was happening at each moment of the chase, and react accordingly.

Digital doubles stood in for wider shots of the characters in their speeders; and, in some cases – most often when Lucas decided to change the framing of a shot – digital body parts were tracked to the footage of the real actors on the gimbaled vehicles. “There is a part of the sequence where Anakin jumps onto Zam’s speeder,” noted Knoll. “She hits the brakes and he slides down to the nose and almost falls off. He’s just hanging on by his fingers, and his legs are dangling down. George wanted to start far away on one of those shots, then have the camera move in close to Anakin as he is hanging off of this thing. But the way we had originally shot it, we were in much tighter, and so his legs were cut off at the bottom of the frame; so when George shrank that plate down to reframe it, we had to add digital legs. We went from fully live-action at the start of the shot, to replacing him from the waist down. Then Anakin kicks his legs up to climb back onto the ship, and at that point we transition back to the full live-action.”

In another shot, Anakin drops his lightsaber, and Obi-Wan catches it. “In the original plate,” Knoll said, “in the performance take that George liked best, Obi-Wan’s hand went up out of the top of frame. It was important that the story point of Obi-Wan catching the lightsaber read – we needed to



A computer animated Dexter was inserted into live-action plates captured on a full-scale diner set in Sydney. Rob Coleman and his animators re-created numerous aspects of voice actor Ron Falk’s on-set performance as Dexter, incorporating into the character the actor’s facial expressions, his bulk and his uneven gait due to a knee injury. Ground-level shots of the diner street miniatures and bluescreened extras created the world outside the diner windows.

see the hand actually grab it – so we pulled back from that, and added a CG hand catching the lightsaber.”

Zam crashes her speeder into the entertainment district, and a foot chase ensues. While the immediate aftermath of the crash was shot on stage in Sydney, the crash of the CG ship itself and the following foot chase took place within 1/8-scale miniature environments. “There were about thirty models involved in that one setup,” said Brian Gernand, “just to get all the buildings, sidewalks, trash cans, lightposts and statues. By the time it was all set up, the street miniature measured fifty feet by twenty-five feet. The buildings were designed so we could reconfigure them in a dozen or more setups.”



Puzzled by the absence of any information in the Jedi temple library regarding the planet Kamino – which Dex identifies as the origin of the toxic dart – Obi-Wan visits Yoda as the master instructs young Jedi trainees. A live-action plate featuring three-to-six-year-old twins was digitally modified to transform some of the human heads into aliens and to clean up the youngsters’ sloppy lightsaber work.

“We just kept taking the same models and rearranging them, turning them upside down or relighting them in different ways,” added Marty Rosenberg, who shot the colorful, Las Vegas-style buildings for an entire month. “Rick McCallum was very keen on building as little as possible and getting as much out of that as possible.”

Anakin and Obi-Wan follow Zam into a crowded nightclub. While the interior was an enormous full-scale set – inhabited by hundreds of local extras dressed in elaborate masks and costumes – the club exterior was built as a 1/8-scale miniature for close shots, and in 1/16 scale for wider views. One of the most prominently live-action scenes in the entire movie, the nightclub sequence featured most of its effects in a betting room off to one side of the establishment, which was built and shot in miniature. “George wanted to show that the nightclub was really more like a sports bar,” explained John Knoll. “So there is a cutaway where Obi-Wan is at the bar and he looks over and sees this betting room. There are a couple of big TV screens in there, showing alien sporting events. One of them is a pod race, one is a droid football game, and one is like greyhound racing, only with alien creatures.”

For the pod race, Knoll’s team added flying pods to a helicopter plate from *The Empire Strikes Back* that had been shot on a glacier in Norway – an oblique reference to the LucasArts pod race game, set on an ice planet. For the animal race, the effects team employed turkey-like CG creatures that had been created for an animal hold scene within a spacefreighter, later omitted from the film. “Those creatures were already done,” stated Jill Brooks, “so we thought, ‘Why not make them racing creatures for this scene?’ We had a matte painting done of the race track, and we added these creatures to it.” Likewise, the droid football game was realized by modifying already existing digital models. “The droids were designs that had been built for other things,” explained Knoll, “and we modified them to make them look like beefed-up football players.” The betting room also had groups of patrons, positioned into the scene by visual effects editor Scott Balcerek.

After a violent confrontation with Zam inside the bar, Anakin and Obi-Wan carry the injured bounty hunter out into an adjacent alley, their aim being to question her regarding the assassination attempts against Padmé. But before she can answer, Zam is shot by a toxic dart, fired by Jango Fett who rockets away. The armored, jet-pack-wearing Jango was a fully digital character. A live-action bar exterior filled the lower-right portion of the frame, and the left side of frame was a miniature wall, with other entertainment street miniatures extending the background.



The full-scale library set, which had consisted only of flooring and a few busts on stanchions, was fleshed out with an expansive miniature. Effects director of photography Pat Sweeney adjusts the miniature prior to filming.

When Zam dies from the toxic dart, her form changes from that of a human female to a Clawdite alien. “Originally,” Knoll recalled, “George had revealed her as an alien in her first scene on the balcony; but he changed his mind, and decided to save it as a surprise for later.” The bounty hunter’s true identity is foreshadowed in a very brief shot in the speeder chase, however, when an angry Zam reveals her alien form for a mere moment.

The transition in the alley death scene was executed as a 3D effect in Caricature. Modeler Sunny Li-Hsien Wei built a rough model from a scan of Leeanna Walsman’s face, which was mapped onto the photographic element of her in the live-action plate. “Sunny then created a series of three-dimensional shapes across the face,” explained Rob Coleman, “dialing in percentages of those shapes to create the transition from the actress to the CG Clawdite.”

With the death of Zam, the Jedi council decides that Padmé and Anakin must go into hiding while Obi-Wan investigates the source of the toxic dart. For the establishing shot of the Jedi temple, the stage crew shot a miniature originally built for *The Phantom Menace*. In addition to Yoda and Mace Windu (Samuel L. Jackson), the Jedi council consisted of performers wearing costumes and masks from the previous picture, plus two all-new prosthetic characters, Kit Fisto and Shaak Ti. “Beginning with color sketches from the design team,” explained Jason Baird, “we first cast actors who closely resembled the characters. From there, lifecasts were taken and the sculpting phase began. We worked on the sculpts over the next two weeks, getting George’s approval at various stages. Once they were finished, we broke down the sculpts and set up multiple fiberglass molds for running the foam latex pieces.”

New CG Jedi characters included Coleman Trebor – named for Rob Coleman – an alien with a small face and a horn at the top of its head. The new character replaced the long-necked alien council member from *The Phantom Menace*, which too closely resembled the Kamino aliens that would be featured prominently in Episode II. Another council member, seen in Episode I, resembled Cousin It from *The Addams Family*, with silver fur covering his face. “The top half of that character was a real performer in makeup,” observed Coleman, “and the bottom half was a CG snake tail. The blend from the CG to the live performer was helped by the folds on the Jedi robe, which made a natural cut line.” Rather than rebuild the Jedi council room, either on stage or as a digital set, Lucas opted to reuse council room footage from *The Phantom Menace*, removing characters from that film and replacing them with the new composition of council members.



As Obi-Wan embarks for Kamino, Anakin and Padmé, disguised as peasants, travel aboard a spacefreighter bound for Naboo. An establishing shot of the pastoral planet featured a foreground spaceport, where the freighter lands, and the capital city of Theed in the background. The final composite was comprised of a digital matte painting of distant hills, practical Theed models first built for *The Phantom Menace*, modular cliff pieces – assembled and shot in various configurations to create an entire rock wall – live waterfall elements recorded with a digital video camera, and a CG spaceport and freighter.

In a following scene, Yoda, Mace Windu and Obi-Wan walk the corridors of the temple, discussing the political crisis now facing the Republic. An animatic of the scene shed light on a logistical problem: the small-statured Yoda, walking with his cane, would not be able to keep up with the walking pace established by the actors in the bluescreen photography. To get around the problem, Lucas decided to have Yoda seated on a levitating device as the trio moved through the temple corridor, which also allowed him to keep the over-six-foot-tall Jackson and Yoda together in frame. The Sabre unit assembled the bluescreen elements with a virtual set, also adding greenscreen elements of generic characters to populate the corridor.



Anakin and Padmé arrive at the Naboo palace for an audience with Queen Jamillia, Padmé's successor to the throne. A matte painting provided the background to live footage shot at Caserta, a centuries-old royal palace in Italy. Filming restrictions at the palace, a popular tourist attraction, precluded the mounting of lights or camera equipment on the walls or ceilings, forcing director of photography David Tattersall to light interiors with illuminated helium balloons floating overhead. Exterior shots took advantage of natural sunlight.

Anakin seeks Palpatine's help in persuading Padmé to go into hiding in a scene that reveals the close bond between chancellor and padawan and foreshadows the former's influence in Anakin's transformation into Darth Vader. Written long after filming had wrapped in Sydney, the scene was shot in London, against bluescreen. To avoid rebuilding Palpatine's office on the London stage, Lucas reemployed the plate of the earlier office scene. ILM erased twenty characters, and added in bluescreen elements of Hayden Christensen and Ian McDiarmid. "That was a very difficult thing to do," commented Pablo Helman, "because that original plate not only had twenty people in it, it also had a boom and a translation of the camera. To do it, we had two monitors on the bluescreen stage in London. On one monitor, we played the original plate; and then we matched that move by eye, looking at the other monitor from the camera to make sure we were in sync. We got it pretty close in only eight takes, and then did some tweaking when we got back to ILM."

Anakin and Padmé return to her apartment, where she packs for the trip to Naboo. The scene presented a continuity problem since, the night before, Obi-Wan had crashed through her apartment window to chase the probe droid, yet the window in the live-action footage of this following scene was intact. To deal with that story point, ILM added background droids who appear to be finishing up the job of replacing the window. Other CG accouterments were a closet full of clothes – not present in the stage set – a table to replace a set piece Lucas disliked, and an art object Anakin telekinetically suspends in midair.

As Anakin and Padmé leave for Naboo, Obi-Wan visits Dexter Jettster, the owner and proprietor of Dex's Diner, in the hope that his wise and well-traveled old friend may recognize the toxic dart that killed Zam Wesell. For a wide establishing shot of the diner, a live-action set was augmented with a miniature and a matte painting by Masahiko Tani.



The miniature street exterior was shot by Pat Sweeney outdoors, and served not only for the initial aerial push-in on the diner, but also for views outside the windows from the interior of the establishment. “We had six or seven building miniatures,” said Sweeney, “each about four feet tall and five feet long, to represent the street. The views were pretty wide, so we took these six or seven buildings to create one side of the street, shot it motion control pushing into Dex’s Diner; and then we took those same buildings, moved them around, changed the rooftops and shot them for the other side of the street. We also shot various moves on those buildings for the window views, as well as bluescreen elements of people walking by, added to the windows in compositing.”

Obi-Wan lands his Delta 7 ship on Kamino, conceived by Lucas and his designers as a stormy planet entirely covered by a roiling ocean, its Tipoca City sitting on stilts high above the waterline. Production shot Ewan McGregor and a full-scale Delta 7 on a partial landing platform set – deluged with rain by the special effects team – then ILM completed the scene with a digital matte-painted sky, Tipoca City models, a CG storm-tossed ocean and live-action spray and mist elements.

Though he appears in only twenty-five shots, the CG Dexter – a vaguely amphibious-looking alien modeled by Frank Gravatt – is one of the movie’s most memorable characters. Dexter’s skin surfaces were made up of Caricature shapes and viewpainted textures. Gravatt and lead Dexter animator Steve Rawlins also devised shapes to create a bullfrog-like neck that could inflate and deflate, the animation timed to correspond with the sound of Dexter breathing in and out.

Animators relied heavily on the on-set performance of voice actor Ron Falk to capture the CG character’s mannerisms and personality. “I remember watching as Ron performed the scene,” noted Coleman. “He had a sore knee, which gave him a slightly uneven gait, and we incorporated that into the CG character. Ron also gave us all these wonderful facial expressions to key off of in the animation.”

A big bear hug greeting between Dex and Obi-Wan proved challenging, as it required direct and sustained interaction between actor and CG character. To more firmly tie the two together, the digital team replaced everything but Ewan McGregor’s head with the Obi-Wan digital double. “We did that so we could really get the feeling of Dex’s hands on his back,” explained Coleman. “We animated the digital double to do what Ewan had done on set, with even his clothing moving in exactly the same way.”

The diner scene also featured a CG droid waitress, built by the hard-surface modelers from a single piece of concept art. In Sydney, live-action had been shot with a real waitress moving through the diner. “They decided they didn’t want the live-action waitress,” recalled roto lead Jack Mongovan, “but a CG droid waitress instead. So we had to remove the live waitress from this panning shot. Because of perspective changes, it was very difficult. If the live waitress was covering up something in five frames, we had to make something up for those five frames when we removed her.”

Dexter identifies the dart as a saberdart from the remote planet of Kamino, inhabited by cloners; but Obi-Wan finds no record of the planet in the Jedi temple library. A minimal library stage set, consisting primarily of large busts of Jedi leaders on stanchions, was completed with miniature busts lined up to extend the row of full-scale busts in the live-action footage. Lead Sabre artist Caitlin Content composited the sequence, integrating the model environment into the live-action set by matching the tracking, lighting and color correction.

Baffled by the lack of documentation regarding Kamino, Obi-Wan seeks the counsel of Yoda, who is training very young Jedi at a temple veranda – another full-size but partial stage set extended through a miniature. Ten sets of three-to-six-year-old twins local to the Sydney area were cast as the baby Jedi, trained to handle their tot-sized lightsabers by stunt coordinator Nick Gillard. Despite the training, however, the children were so young and inexperienced, much manipulation of the scene was required after-the-fact. “The prop versions of the lightsabers were not as long as they should have been,” recalled CG supervisor Henry Preston, “so when we added the lightsaber effect, their wands would be cutting off the heads of the kids next to them. The lightsabers were also all over the place, so we had to rotate the handles to make the rods point the right way and keep them from intersecting with these little craniums. We repositioned lightsabers, kids, body parts – those shots wound up being almost completely synthetic by the time we were done.”

More digital manipulation transformed some of the human baby Jedi into alien trainees. “We shot a little-kid body double here at ILM, wearing a costume,” Coleman, explained, “and just replaced his head and hands with a variety of aliens: a red-and-white-faced creature, one with an alligator head, and another with horns all over its face. The modelers created these very sweet little baby alien faces.”

The film cuts from Obi-Wan’s departure for Kamino to Anakin’s and Padmé’s arrival on Naboo via starfreighter. An opening Naboo rebel unit shot has air buses landing and taking off as the starfreighter docks at a spaceport, with the city of Theed, cliffs and waterfalls visible in the background. The foreground spaceport area, dubbed the ‘wharf,’ was all CG imagery. “Colie Wertz built the entire wharf area in 3D,” said rebel unit lead Erich Ippen. “It consisted of two levels with little piers jutting out. There were also several buildings in the area, and ships lined up on the waterfront.” Parked on a background landing platform of the spaceport are two gleaming, new Millennium Falcons.

Backdrop cliffs were miniatures, built in a modular fashion so they could be assembled and shot according to the camera moves worked out by the rebel unit. “They built one cliff that was concave,” said Ippen, “one that was convex, one that was in the shape of an ‘S’ and one straight piece, each



Modelmakers Roy Sutherland and Jeff Brewer detail the Tipoca City miniatures. To blend the miniatures with 3D CG elements in the Kamino establishing shots, visual effects supervisor Pablo Helman had his team execute digital camera moves over the digital ocean, then sent those files to the miniatures stage, where the moves were replicated on the Tipoca City models.

about four feet high and six feet wide. The miniature photography crew positioned them around, shooting a number of different elements that could then be assembled to create this whole wall of cliffs. We had to cover all the camera angles that might be needed, so there were a lot of different setups.” Waterfalls tumbling from the cliffs were digital video elements shot by Paul Huston in northern California. On top of the cliffs and in the background sits the city of Theed, made up of practical models created for Episode I, shot by Marty Rosenberg.

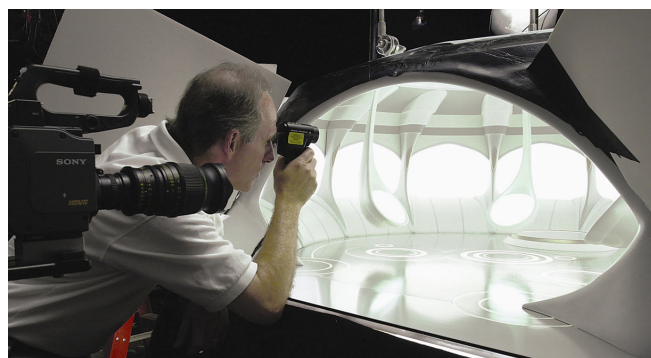
Subsequent shots of Anakin and Padmé in a Theed plaza were filmed near Seville, Spain during principal photography. A local bridge was included for its picturesque quality, but since many of its supports were badly damaged, they had to be replaced with digital structures. A matte painting filled in the palace in the background and much of the area surrounding the plaza so that, in the end, the Spain live-action footage made up only one quarter of the frame.

Anakin’s and Padmé’s audience with Queen Jamillia was filmed within the palace at Caserta, Italy, which had served for Episode I’s palace interiors, as well. The scene required the addition of Sio Bibble, the queen’s advisor, since London-based actor Oliver Ford Davies was not able to travel to Italy at the time of the shoot. “Since he couldn’t be there,” explained Helman, “they just shot a stand-in for him at the location. Then, when we went to London to do additional filming, we shot him separately, bluescreen, and added him to the scene later. The hard part was that he had to go down stairs that were in the palace footage; so we shot him descending some bluescreen stairs and tied him to the original plate.”

Also added to the stairs in the palace was a computer generated R2-D2, employed throughout the movie for stunts that were impractical or impossible to achieve with the mechanical droid.

The assignment went to lifelong R2-D2 enthusiast Billy Brooks of the rebel unit, who had built a digital R2-D2 used for one shot in *The Phantom Menace*. Brooks revamped that CG model’s geometry and textures to make it look more like the R2-D2 from the original trilogy – something for which droid engineer Don Bies had lobbied hard. “I’m glad Don pushed for that,” Brooks said, “because it looks a lot better. His head is much more metallic and his blue parts are like car paint, very high-gloss. Working closely with Don, my goal was to copy that exactly.”

Brooks produced the CG R2-D2 almost entirely in LightWave. “I’m a LightWave user from way back,” said Brooks. “I tweaked the model in FormZ and the LightWave modeler. I textured it in LightWave, animated it in LightWave, and lit and rendered it in LightWave. LightWave had some terrific tools, such as radiosity, which really nailed the look by calculating bounced light and darkening areas in which the light was occluded.”



Mistaken as an emissary of Jedi Master Sifo-dyas – who commissioned the Kaminoans to build a clone army ten years earlier – Obi-Wan is introduced to Kamino Prime Minister Lama Su. The official’s glowing white office was built and photographed as a model, into which bluescreen footage of Ewan McGregor was incorporated. When an early test composite of the bluescreen and miniature photography revealed that McGregor appeared to walk through one of the model’s illuminated chairs, the miniature prop was replaced with a CG chair, animated to descend from the ceiling after McGregor had passed. Pat Sweeney lines up a shot on the office miniature.

After their audience with Queen Jamillia, Anakin and Padmé go into hiding at a beautiful lake retreat, shot at Lake Como in northern Italy, at the centuries-old Villa Balbianello estate. Matte painter Mathieu Raynault replaced sections of the villa exterior with more fantastic-looking, Naboo-style architecture through 3D matte paintings, and also added a distant matte painted island. Caitlin Content of the Sabre unit massaged in live water plates to transform the peninsula on which the villa sat into an island.

Other effects devised for the predominantly live-action sequence were of the invisible variety, enabling Lucas to create performance subtleties after the fact, regardless of what had been captured on location. “George wanted a specific performance from Anakin in a shot of him and Padmé on a balcony overlooking the gardens,” recalled Pablo Helman. “George wanted him to stroke Padmé’s hand; but in the take George liked, Hayden hadn’t done that. So we shot somebody’s hand doing the stroking movement, and replaced Anakin’s hand with this stroking hand.”

Later in the sequence, Anakin and Padmé share a picnic on a beautiful meadow as shaaks graze nearby, the live-action for which was also shot at Lake Como. To extend the location meadow into a rolling hillside, Paul Huston constructed a hilly miniature, carpeted to simulate a grassy texture. Huston also provided a background wall of waterfalls for the scene, using the same live digital video elements featured in the opening Naboo spaceport shot. When Lucas decided to extend the picnic scene beyond what he had captured at Lake Como and add wider views, Jeff Doran and his compositors had to grab live-action elements of Anakin and Padmé from the location plates and track those into digimatte environments.

During the picnic, Anakin shows off for Padmé, riding one of the bovine shaaks rodeo-style. Hayden Christensen rode a blue-covered shaak form mounted to Dave Young’s gimbal. Final shots incorporated the live-action with matte painted backgrounds and 3D computer animated shaaks.

While Anakin and Padmé fall in love amidst the natural beauty of the Naboo retreat, Obi-Wan pilots his Delta 7 ship toward Kamino. Pablo Helman’s unit was responsible for establishing shots of Obi-Wan’s arrival, which featured wide views of the planet’s storm-tossed seas, out of which rise the structures of Tipoca City, a miniature shot by Pat Sweeney, with digital matte paintings by Wei Zheng filling out the background. In two of these Kamino exteriors, a flying air-whale breaches through frame. “We were told that George has been trying to get that air-whale into a *Star Wars* movie since *Empire Strikes Back*,” revealed Gretchen Libby. “He’s had this creature design ever since then. There are only two shots of it – one where it comes out of the water, and another where it flies under Tipoca City – but George finally got that creature into a movie.” The shots were composited by R. Jay Williams.



*The computer generated Kaminoans – both Lama Su and aide Taun We – were a departure in the Star Wars universe in that they closely resembled the popular perception of large-eyed, small-mouthed aliens, Lucas’ intentional nod to the UFO phenomenon and friend Steven Spielberg’s *Close Encounters of the Third Kind*. Viewpainters based Kaminoan skin characteristics on amphibians – suggesting the creatures may have originally lived beneath their planet’s oceans – while animators endowed them with a graceful, ethereal style of movement.*

Helman's unit created a digital camera move over a CG ocean for the shots, and that file was then sent to the miniatures stage, where the same move was executed on the Tipoca City miniature. The CG ocean benefited enormously from the intense research and development ILM had done for *The Perfect Storm*, though the Kamino sequence called for a different application of those tools. "*The Perfect Storm* was all about the ocean," observed sequence supervisor Samir Hoon, "but these Kamino shots were distant, and they weren't really about the ocean. So, instead of doing oceans for every single shot, we worked out a technology where we could use oversized renders with different layers for all the different views that we needed. We started with the setup we had for *The Perfect Storm*, then enhanced the shader to give these shots a different look."

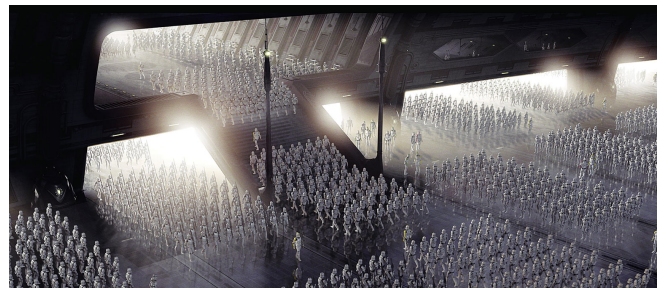
"The ocean in these shots had to look vast," added Helman, "and we realized early on that what made it look vast were beams of light shining on an area of the water. So we engineered our shots so that one section of the ocean was always brighter than the other."

On stage in Sydney, production shot Obi-Wan emerging from his ship on a landing platform set, pelted by the planet's ever-present rain. Dave Young had rigged an elaborate rain system in the stage ceiling to create a widespread and controllable rainfall. On the platform, Obi-Wan is greeted by Taun We, one of the graceful, tall Kaminoans, conceived by Lucas and his designers to resemble the classic aliens of *Close Encounters of the Third Kind*. The characters would be portrayed entirely as digital creatures. "We had a Ranch maquette of the head," recalled Geoff Campbell, "and a naked maquette that showed all of the anatomy, which was really quite beautiful." Moon-Jung Kang built flowing costumes for the lead Kamino characters, based on sketchwork from the Ranch. Viewpainters referenced amphibians for the Kaminoans' skin quality, which suggested a species living in a water environment.

Rob Coleman engaged in a number of discussions with Lucas to nail down the quality of the Kaminoans' movement. "We talked about them doing Tai-chi type movements," Coleman related, "or walking like runway models. They are very tall, with feet that look somewhat like hoofs, and they walk up on their tip-toes. They have large hands, which they move in a fluid manner when they speak. Then,



Obi-Wan's tour of the Kamino cloning facility takes him through a vast hatchery where clone fetuses – developed from the DNA of bounty hunter Jango Fett – are grown. When Lucas decided to position the virtual camera closer than originally intended, digital artists created a suggestion of movement and life by animating the glass-encased fetuses. They also applied different paint details to suggest that the clones were at various stages of gestation. Compositors sweetened the shots with lens flares and reflections to make it appear as though light was bouncing off the hundreds of glass vessels.



The last stop on the tour showcases thousands of fully-grown, combat-trained clones – predecessors to the Imperial stormtroopers introduced in *Star Wars* – marching in formation. Since production opted not to build even a single trooper suit, every armored and helmeted clone trooper featured in the film was a fully computer generated character. Marching and other basic combat actions were motion-captured at ILM, then applied to the digital clone troopers for animation.

whenever they stop talking or walking, we animated them to settle into a certain hand pose, almost like sign language.”

Mistaken as an emissary of the mysterious Jedi who ordered the creation of a clone army a decade before, Obi-Wan is taken to the office of Prime Minister Lama Su. Bluescreen elements of Ewan McGregor were composited into a miniature office set, photographed by Pat Sweeney. Computer generated elements added to complete the miniature in final shots included doors that opened and closed. “In one of the shots,” related CG supervisor David Meny, who was instrumental in developing all of the Kamino interiors, “there is an illuminated CG chair that descends from the ceiling, created using Mental Ray for detailed reflections.”

The descending CG chair was a late idea conceived to fix a discrepancy between the live-action bluescreen plate – in which Ewan McGregor sat on an illuminated practical chair, there only to throw ambient light on the actor – and the miniature photography. “The practical chair was in a different position than the one shot on the miniature,” explained Helman, “and, in the stage plate, Ewan walked right through the area where the miniature chair was. So we had to remove the chair from the miniature and put in a CG one descending from the ceiling. Fortunately, we had shot the miniature both with and without the chair, in case there was a problem.”

A similar problem arose in the shot of Obi-Wan first walking into the room: when that bluescreen element of McGregor was lined up with the miniature photography, the actor appeared to walk through a wall. “Fortunately,” sequence supervisor Leandro Estebecorena noted, “we were able to use the element that Pablo had shot of the miniature, map it on a cylinder, and rotate it around so the miniature doorway matched better with the bluescreen.” Jeff Doran’s compositing team blended the miniature and CG architecture with the bluescreen live-action elements, and tracked in the 3D Lama Su and other Kamino characters.

The Kaminoans give Obi-Wan a tour of the facilities, where he sees clones – grown from the DNA of Jango Fett – in various stages of development. Live-action for the tour corridors, situated above the various cloning rooms and featuring wide glass panels, consisted only of McGregor walking the length of a bluescreen stage. Those live-action bluescreen elements were composited into miniature corridors.

Although the Ranch had provided designs and animatics for the tour sequence, ILM visual effects concept artist Michael Brunsfeld came up with a new look for many of its features when Lucas made a late-date decision to redesign the segment. David Meny worked with Pablo Helman to create a new set of animatics, the files from which were used in filming the corridor miniatures. The tight effects budget again dictated that maximum coverage be obtained from minimal sets. “We only had three miniature corridor pieces,” explained Helman, “one straight piece and two curved pieces, and we had to make sure that all the shots in the sequence could be covered with those three miniatures.”

Whereas the miniatures provided the interior walkways that Obi-Wan and his CG companion traverse in the course of the tour, the different rooms seen from those walkways were created through a combination of greenscreen or bluescreen elements and CG environments.

First stop on the tour is the hatchery, a huge, digitally concocted space filled with hundreds of glass-encased fetuses hanging from mechanized racks. “The CG hatchery was one of the most complicated rendering setups ever,” admitted David Meny, “primarily because there were so many of these jars with fetuses. There were 102 jars on each pod, and in a number of the shots, you can see 50 or 60 pods. We wanted to put as much detail in these shots as we could, so we ended up using a ray tracer, Mental Ray. Ray tracing is notoriously slow, but it gave the environment its ambient, bounce lighting and all the refraction of the jars as they moved against each other.”

The hatchery shots were complicated when Lucas decided to move in closer on the pods than originally planned. “We ended up having to do animations of the fetuses moving,” recalled Meny, “and putting in fingers and toes, and doing different hair paint jobs, just to make them look as if they were at different stages of gestation. We did as much duplication as we could – fortunately, there was a lot of symmetry throughout this – but to take the CG curse off of it, we also had to put in some variation, so that you didn’t feel as if you were seeing exactly the same thing duplicated throughout the space.” Jeff Doran, Cathy Burrow and Barry Safley finessed the shots in compositing, adding flashing and lens flaring to create the illusion of light reflecting off the glass jars.

A stop at the training room reveals hundreds of young boy clones training for battle at consoles. Daniel Logan played the young clones, as well as Jango Fett’s clone son, Boba, promised to the bounty hunter in return for his DNA. The training room scene was created by compositing multiple greenscreen elements of Logan shot at ILM. “Marty Rosenberg shot the boy at a single console against greenscreen,” explained Helman, “then moved the actor and the console from one position to another, shooting him something like 175 times. Then those were assembled by visual effects editor Scott Balcerek.” The same technique was used to create multiple twenty-year-old clones in the commissary, with Rosenberg shooting actor Bodie Taylor a total of 99 times, in various positions, on a set at ILM.

For scenes in which the clones were in full armor – looking very much like the stormtrooper predecessors they are – the characters were computer generated models, created by Bruce Holcomb of the hard-surface modeling team, who did all the armor, and creature modeler Dylan Gottlieb, who modeled the softer cloth areas in between, as well as the gloves.

Though the clone trooper is supposedly an exact copy of Jango Fett, the concept maquette of the character was proportionately taller and thinner than actor Temuera Morrison; and so the CG model had to be revised somewhat from the original maquette. “We tried to squeeze the clone trooper onto our CG Jango Fett skeleton to make him the real size,” noted Russell Paul, “but when that didn’t work, we modified it a bit. So, even though he should have been exactly the same size since he was a genetic copy, the clone trooper was a slightly different size than Jango.”

The CG clone trooper was used for *every* armored clone shot in the picture, as not a single practical trooper suit was built by the production. “Anytime you see a helmeted, armored clone, it’s a CG character, even in closeups,” confirmed Rob Coleman. “We knew from the beginning that there wasn’t going to be a clone trooper suit. We were pleading with them – ‘Please, at least for the closeups, build a suit!’ – because the level of detail we had to build up in the model for a closeup was tremendous. There were a couple of shots right over the shoulder of a clone trooper as he turned into camera, and those had to hold up on the big screen.”

Most of the CG clone trooper actions were realized through motion capture, supervised by Jeff Light, using ILM staffers as motion capture subjects. “Since they were human characters, covered in armor and helmets, they were perfect for motion capture,” Light said. “I was excited to be working on it, because I’d been hearing about the clone wars ever since the first *Star Wars*. But it was a daunting task, because there were going to be thousands of these characters in the training scenes and later clone war scenes, all doing different things.”

Because the CG clones would often be populating miniature environments, Light would calculate the scale of the miniature, take the camera matchmove of the miniature photography, which was a CG representation of the plate, and make tape marks on the floor of the stage accordingly, marking off the height of a ship console, for example, so that the spatial relationships in the miniature could be re-created on the motion capture stage. “When the motion capture actor went to hit buttons or lean on a surface,” explained Light, “we had made that corresponding set on the stage so that it would translate to the miniature. Body language could be captured on stage with our mocked up set, which totally sold that the character was really in that miniature space.”

After a terse meeting between Obi-Wan and Jango Fett in the bounty hunter’s apartment, the two square off on the landing platform where Jango’s Slave I ship is parked. The Slave I – introduced as Boba Fett’s ship in *The Empire Strikes Back* – was built by the hard-surface model team, which relied upon photographic reference from that film, since the actual model was on exhibit at the Smithsonian. The only practical part of the ship built in Sydney was the cockpit, for shots of Jango at the controls. “Even when Jango runs up the ramp of the ship,” stated Russell Paul, “that was the CG Slave I. They had a real Jango running up a bluescreen ramp, and just combined that element with our ship. That shot shows the interior of the ship up fairly close, so it had to be very detailed. Overall, the detail level was very high in these shots, many of which had the model more than filling the screen.”

Live-action for the intense fight between Obi-Wan and Jango Fett that follows was shot on a partial set, extended with a multi-tiered CG platform. The scene also featured bluescreen elements of the actors and their stunt doubles, as well as digital doubles. Like the clone troopers, the CG armored Jango was often motion captured; but because the fight sequence had Jango performing feats of acrobatic skill beyond what a motion capture performer could do, including flying, the character was frequently hand-animated. The digital double assignment was complicated by the practical rain, which required the digital simulation of water dripping off the characters’ clothing.

To expedite the sequence, one hundred of the fight shots were composited by the Sabre unit, supervised by Dean Yurke. One of the challenges of the Obi/



Obi-Wan confronts Jango Fett on the landing platform as the bounty hunter attempts to depart Kamino. For the ensuing battle, live-action photography of Ewan McGregor, Jango actor Temuera Morrison and their stunt doubles was enhanced and augmented with digital doubles of both characters. *Attack of the Clones* represented ILM’s most extensive digital double assignment to date, enabling Lucas to conceive and execute dynamic stunts without concern for the limitations and logistics of traditional stunt setups, which often dictate multiple cuts and restricted camera angles.

Jango fight, which took eight full months to complete, was creating the look of the lightsabers in the rain, and in HD. “Because of the HD format,” said Yurke, “the lightsabers didn’t work the way they used to. It took a long time to get the lightsabers to look right; and then they went out to film and looked different again! So we had to go back and figure out how the lightsabers should look in the HD so that they would look right by the time they got to film.

“We also had to come up with a way to do rain and Jango’s jet thrusters, both of which were generated in the Inferno particle system. There is a shot where the jet-pack flies off Jango and smashes into a building and explodes. To save time, we imported the jet-pack model into Inferno and animated it – the explosion, thrusters and rain, all in one system, saving the use of an animator, technical director and compositor. Pablo, whose background is in this kind of system, was great about pushing what Inferno could do.”

Believing Obi-Wan to be dead, Jango and Boba Fett escape in their Slave I; but the resourceful Obi-Wan is soon on their tail. Back on Naboo, Anakin suffers disturbing nightmares about his mother and decides he must return to Tatooine. Padmé insists on going with him, and the two depart in her chrome starship, modeled and rendered to resemble the queen’s ship from Episode I. Michael Jackson in the rebel unit reengineered the original queen’s ship model and re-created textures for both Padmé’s starship and the Naboo cruiser seen in the opening sequence. “One of the problems with the original queen’s ship was that it had so many render passes,” noted Erich Ippen. “So, for this ship, Michael devised ways of combining render passes into different channels so that it wouldn’t be so cumbersome.” The rebel unit produced every shot of Padmé’s dart-shaped, chrome ship seen in the film.

Anakin and Padmé arrive on Tatooine, their starship landing within one of three circular hangars, a model shot by Marty Rosenberg. The pair immediately visits the Mos Espa junk shop of the slave-trader, Watto. Production had returned to the Episode I Mos Espa set in Tunisia to shoot the sequence. In postproduction, John Knoll’s unit extended the set with digital matte paintings, and also incorporated the digital Watto model from Episode I. “Watto gave us a chance to depict an already-established character, but after ten years had elapsed,” observed Knoll. “We reworked him and changed his viewpoint to make him look like he had aged. He also has different clothing, and a full beard.” Watto’s clothing was built by Moon-Jung Kang.



*Detected while tracking Jango and his clone son, Boba, in their Slave I getaway ship, Obi-Wan is ambushed and chased through an asteroid belt surrounding the planet Geonosis. Reminiscent of the similarly staged asteroid dogfight in *The Empire Strikes Back*, the sequence – unlike its model-dependent predecessor – made use of digital ships flying through computer generated rocks. Though the technology was new, John Knoll maintained continuity by adhering to the overall style of the original.*

Having learned that his mother was sold to, and eventually married, moisture farmer Cliegg Lars, Anakin and Padmé travel to the farm, situated near the remote Mos Eisley. Live-action was shot in Tunisia, at the same two locations that had served the original *Star Wars* – one, a salt flat on which the homestead’s igloo-style buildings were erected; the other, underground troglodyte dwellings.

Introduced to his step-family – Cliegg, his son Owen, and Owen’s girlfriend Beru – Anakin receives the sobering news that his mother has been captured by Tusken raiders.

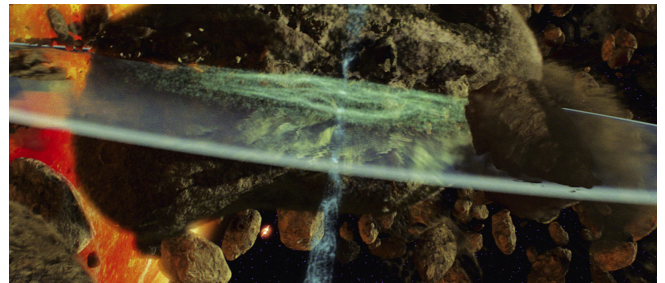
In addition to Gavin Bocquet’s refurbishing of the Tunisian film sites, the homestead scenes required some postproduction manipulation, such as the removal of Anthony Daniels from plates in which he operated the C-3PO bunraku puppet from *The Phantom Menace*. “That required a lot of roto work,” observed Jack Mongovan, “because you could see the puppeteer not only behind C-3PO, but between all of his exposed wires.” To accommodate specific performance nuances requested by Lucas, the puppet in many of those live-action shots was ultimately replaced with a CG 3PO or a 3PO element shot against greenscreen at ILM.

Determined to bring his mother home, Anakin takes off that evening on a speederbike, crossing the desert in a montage of shots that span from sunset to deep night. Bluescreen elements of Hayden Christensen on a banking speederbike were composited into 3D terrain. Pablo Helman’s unit resurrected the pipeline that had been developed for the pod race in *The Phantom Menace*, which had likewise required a variety of landscapes rushing by at high speeds. “Once we’d resurrected that whole pipeline,” said Samir Hoon, “it was just a matter of coming up with the look of the landscape, matching to artwork from the Ranch.” Digital matte paintings by Wei Zheng provided far background and sky, rendered separately from the CG terrain. Rendered elements were then assembled by the Sabre unit.

One shot has Anakin riding off into a twin-sun sunset. “Samir Hoon gave me the 3D terrain elements,” Dean Yurke explained, “and I put in the 2D background mesas, spacing them out using the matchmove inside Inferno. Then I added the bluescreen speeder elements to that collage of images.” Yurke also sweetened the shot with lens flares, matching the look to the closing, off-into-the-sunset shot of *Easy Rider*. “I was watching *Easy Rider*, and I noticed there were lens flares and a barrel around the edge of frame in that shot. So I copied that, because this really was an *Easy Rider* shot.”

At the end of the montage, in a wide nighttime shot, Anakin is seen atop a cliff – a miniature – overlooking a digital matte painted Tusken raider

camp below. In a following shot, the Anakin digital double jumps from the cliff miniature. Anakin’s approach of the camp and his entry into the hut where he finds his mother, beaten and tortured, was shot in Sydney, on a set featuring only two huts and a campfire. Wider shots were filled out via digital matte paintings and a 30-by-30-foot, 1/48-scale Tusken village miniature, shot by Ray Gilberti. “We handmade the huts out of vacuform,” said Brian Gernand, “then stippled on texture. We created campfires with little flicker lights.” The effects team also composited in computer animated massiffs – dog-like lizards that fight over a bone at the campsite.



A seismic charge fired from Jango Fett’s ship obliterates an asteroid, the explosion followed by a digital shockwave effect. One of the boulders blown up in the course of the dogfight was a NASA low-resolution model of Eros, a massive real-life asteroid situated between Mars and Jupiter. The original asteroid models from *The Empire Strikes Back* were scanned to create textures for the CG versions. A ‘crater generator’ employed particles to distribute procedural textures on the CG asteroid surfaces.

After his mother dies in his arms, Anakin storms through the camp, indiscriminately killing Tusken men, women and children, and later confesses his act of violence to Padmé in the garage of the homestead. The scene was shot on a set in London, with bluescreen positioned for the later insertion of adjacent rooms. “We put CG sets in for two additional rooms,” said David Meny, “as well as a CG skyhopper and land-speeder parked in the garage. Those shots were interesting because you see that same set in *Star Wars*. We had to look back at that sequence and make sure we had the same look in terms of the textures and lighting.”

Anakin and his step-family bury Shmi at the homestead. The live-action funeral sequence had a continuity error that had to be corrected by Jeff Doran’s compositing unit. “There was a shot of Padmé,” said Doran, “with Anakin’s cloak and shoulder in the right side of frame – which shouldn’t have been there, since he had dropped to his knees in front of his mother’s grave in the cut just before this. So we had to remove his shoulder, which wasn’t all that challenging in itself; but we also had to reframe the shot so that Padmé was centered, which meant we had to come up with architecture for the hut behind her, and also fill in some desert floor and sky. We searched through all the shots from that location and found a similar camera angle of that hut, blew up that element 400 percent, tracked it and split it in so it looked like it was photographed that way in the first place.”

Across the galaxy, Obi-Wan continues to track Jango Fett’s Slave I, engaging the bounty hunter in a dogfight through an asteroid belt surrounding the Red Planet of Geonosis. “The dogfight in the asteroid field was reminiscent of the famous asteroid scene in *Empire Strikes Back*,” John Knoll commented. “I was very impressed with that scene when I first saw it; so the idea of doing something similar using today’s technology was very appealing to me. But there was a stylistic legacy that we had to be conscious of. I wanted to make sure these shots felt familiar and that the environment had some resemblance to the one in *Empire Strikes Back*.”

While the scene in the older film was accomplished by shooting spaceship and asteroid models motion control, and the new sequence – supervised by Chris

White – was computer generated, Knoll ensured a continuity of design by retrieving some of the asteroid models from *The Empire Strikes Back* from the Lucasfilm archives. “We scanned those models to get the textures,” said Henry Preston, “then we used a Maya interface tool for building the asteroid field. We also had a crater generator, which used particles to procedurally distribute textures on the surface. We could paint craters and get thousands of rocks detailed very quickly and easily.” During the dogfight, Jango engages his ship’s weapons, at one point blowing up a giant asteroid – in actuality, a low-resolution NASA model of Eros, one of the large asteroids in the belt between Mars and Jupiter.



On a quest to find Anakin’s mother – left behind on Tatooine ten years before – Anakin and Padmé disobey Jedi directives by journeying to the remote desert planet in the senator’s chrome starship. The ILM rebel unit, working outside the company’s main CG pipeline, produced every Naboo starship shot in the film. The landing approach took place over miniatures representing the city of Mos Espa, shot by effects director of photography Marty Rosenberg. Extending the models – which included three circular hangars – were background matte paintings of the city.

Jango lands on the surface of Geonosis, a red-rock planet realized through minimal sets built in Sydney and a number of real-world miniatures, CG set extensions and matte paintings. For the nighttime shots of Jango's – and, subsequently, Obi-Wan's – flyover approach, landscapes were created entirely through 3D digital matte paintings by Brett Northcutt, Susumu Yukuhiro and Colie Wertz, into which the CG Delta 7 and Slave I ships were incorporated.

After landing, Obi-Wan explores corridors carved out of rock, overhearing a conversation between Dooku and his co-conspirators within a subterranean conference room – a live set, built and filmed in England. Shots of Obi-Wan’s lurking within the surrounding hallways were achieved by compositing bluescreen footage of Ewan McGregor into a spire-and-archway miniature, photographed by Pat Sweeney, while wide shots featured 3D matte paintings by Mathieu Raynault.

Some of the characters in the scene were masked performers, while others, such as the wasp-like Geonosians, were computer generated. Frank Gravatt modeled two classes of Geonosians – one, a winged ‘royalty’ class, the second, a wingless drone – and, within each of those classes, modeled distinctive body and head types to ensure adequate variety in wide shots featuring thousands of the creatures. Different viewpaint schemes multiplied the number of possible looks. The most distinctive of the Geonosians is their armored leader, Poggle the Lesser, created by lead modeler Andrew Cawrse and painted by Steve Walton.

Since the initial Geonosian design had been based on termites, wasps and grasshoppers, Rob Coleman used the insect world as a touchstone in animating the characters. “They have wasp-like legs hanging down when they fly,” Coleman noted, “and they have double sets of wings, which we based on dragonfly wings. We discovered in our research that dragonfly wings don’t really move up and down that much. They hover. So we used that motion for later scenes in which the Geonosians are panicked; and then, when they’re moving more slowly, we patterned the wing movement off of moths.”

While transmitting a hologram message regarding the imminent military confrontation being planned by Dooku and his conspirators, Obi-Wan is captured and taken to a prison cell, where he is suspended in laser-like hand- and leg-cuffs. Ewan McGregor was shot within a smoke-filled cell set, and was suspended by wires, removed by the roto team in post. “The difficult part of that,” said Jack Mongovan, “was getting rid of the wires but retaining the



Modelmakers Ira Keeler, John Goodson and Lauren Abrams ready the Mos Espa miniature for filming outdoors. Though the miniature environment served for wide establishing shots, live-action street scenes were filmed in Tunisia, on a full-scale Mos Espa street set, originally built for *The Phantom Menace* and maintained in the three years between productions.



Veteran modelmaker Steve Gawley, who has worked on all five Star Wars films, adds finishing touches to the Mos Espa setting.

smoke. The shadows from the wires fell across his face and clothes, and we had to get rid of those, as well.”

On Tatooine, after receiving the aborted message from Obi-Wan, Anakin and Padmé set a course for Geonosis, taking R2-D2 and C-3PO with them. Christensen and Portman were shot on a ship interior set in London, while C-3PO and R2-D2 were shot separately, bluescreen. Because the 3PO suit was not jointed to allow for a seated position, shots of the droid sitting were performed by Anthony Daniels wearing only its top half. “The original idea was that we would just replace his lower body with a CG 3PO,” recalled Robert Marinic. “But we realized that it was going to be more difficult to track that CG lower half to the bluescreen upper half than it would be to replace the whole thing. So we used our CG 3PO for those shots.”

Obi-Wan’s message is also received by the Jedi council, the chancellor and the members of the Senate. In response, Jar Jar proposes an emergency measure on the Senate chamber floor, moving to endow Chancellor Palpatine with emergency powers and extend his term in office indefinitely – a move that will have catastrophic consequences for the Republic. The Senate chamber scene featured the CG set built for Episode I, while the background assemblage was made up of sprites – small 2D cards onto which photographs of costumed ILM staffers were mapped. Greenscreen elements shot for the Senate scene in Episode I were also used to populate the chamber. “We used that whole library of characters from Episode I,” affirmed Robert Marinic. “Lead technical director Kevin Sprout catalogued hundreds of elements and wrote scripts to sort through which ones would work with what camera angles.”

Even with those hundreds of greenscreen characters, the artists did not have enough to cover all the camera angles in the new scene. To provide additional elements, Marty Rosenberg shot bluescreen footage of ILM performers in senatorial costume. “We set four cameras up at different heights,” recalled Rosenberg, “put people on a platform, and shot hundreds of elements in a day, rotating the platform to give us different angles and perspectives on the performers. We had twelve groups of performers, three to five people in each, and we mixed and matched those to fill the Senate chamber.”

Anakin and Padmé land on Geonosis in a rebel unit flyover featuring the chrome Naboo starship and digital backgrounds. Unlike the earlier nighttime approaches, the daytime flyover would fully reveal the planet’s rocky terrain. Dennis Muren and Ben Snow initially had hoped to shoot location plates for the alien landscapes; but that idea was rejected by the budget-conscious production as too expensive. As an alternative, the supervisors suggested shooting still photos at some



Learning that his mother has been abducted by barbarous Tusken raiders, Anakin travels by speederbike to the raider village, where he vents his rage at her death by slaughtering every man, woman and child in sight. A small live-action set, consisting of only two huts, was expanded via a thirty-foot-square miniature for wide establishing shots of the Tusken encampment. Texture was stippled onto vacuform huts by hand. Pablo Helman lines up a test shot as modelmakers Pierre Mauer and Barbara Affonso work on the village miniature.

appropriate location – a less costly proposal than shooting moving footage – then stitching that photography together to create panoramic backgrounds. Fortunately, lead digital matte artist Jonathan Harb had only recently returned from a vacation near Moab, Utah, bringing back with him photographs of red rock landscapes and interesting formations. “We thought that many of these images looked just right for Geonosis,” said Ben Snow. “So we grouped Jonathan’s photographs into panoramas. Then we showed them to George, and he said, ‘Yeah, that’s it.’” Soon afterwards, Harb returned to the southwest locations with Snow and Marty Rosenberg. “We shot fifty rolls of stills and CDs full of digital stills, and stitched them together to use as source material.” In addition to the stills, the group gathered maps and all available United States Geological Survey data from the area, all of which would be instrumental in assembling the photographic backgrounds.

While the photographic material would provide distant backgrounds, CG terrain – developed by sequence supervisor Hayden Landis and lead technical directors Kevin Sprout and Tommy Burnette – would be used for midground and foreground landscapes, along with miniatures. The first full reveal of the Geonosian landscape, in the approach of Padmé’s ship, was almost entirely a CG terrain, with only a bit of still photograph and matte painting background. The CG geometry was mapped with procedural and photographic rock textures.

Guided by the coordinates indicated in Obi-Wan’s message, Anakin and Padmé land near a steam vent of a factory where battle droids are being mass-produced. “The factory wall was a miniature,” observed Ben Snow, “then, in the foreground, there was another miniature walkway and a little platform that the ship sits on.” Erich Ippen added the CG ship on the miniature platform, and compositors blended in practical steam elements. “We knew we were going to need sparks, smoke, explosions and steam throughout the droid factory sequence, so Dennis Muren supervised a pyro shoot to get a variety of elements that we could pull from.”



Visual effects supervisor Ben Snow and digital matte sequence supervisor Jonathan Harb review art department renderings of rocky formations characteristic of Geonosis, the setting for the film’s concluding act. The planet’s landscapes were realized entirely through miniatures, CG terrain, 2D photographic panoramas and digital matte paintings.

Inside the droid factory, Anakin and Padmé walk down long dark corridors, passing through the sleeping chamber of Geonosian workers. The actors were shot on stage, walking through a bluescreen environment, and that element was composited with a miniature chamber. “We felt that a miniature would be the best approach,” Snow explained, “so Brian Gernand’s team built a detailed miniature of one side of the sleeping chamber. Our matchmove team matched the original bluescreen photography of Padmé and Anakin, and we sent it out to the motion control stage, where Marty Rosenberg shot dark, moody plates of the miniature chamber. We also shot a pass to get the data for our photo-modeling version of the chamber, built so that we could cast shadows of the Geonosians nestled in the walls. It was just a crude version, built specifically to cast those shadows.”

Disturbed by the presence of Anakin and Padmé, Geonosian workers emerge from the crevices in the rocks, advancing on the pair until they are separated within the bowels of the factory, each winding up in a different area of a massive production assembly line. Because the droid factory was added relatively late in production, artwork and animatics pertaining to the scene were sketchy; and, as a result, the Muren/Snow unit had to develop the details of the environment and the sequence of actions nearly from scratch. “We had some nice paintings of the factory from the Ranch,” said Snow, “but we didn’t have specific artwork that laid out: ‘Here’s what each machine looks like and here’s what each machine does.’ Doug Chiang did do some line drawings and we were able to extrapolate from those somewhat.”

Early in its exploration of the droid factory, the Ranch art department had sought inspiration in a nearby automobile manufacturing plant. Snow and his team did the same when it came time to produce their shots. “We took some of our painters, modelers and R&D people out to tour the plant,” recalled Snow. “We also went to a foundry nearby. It was dirty and dark and nasty – everything I was hoping we’d get into the droid factory. We shot reference and texture material there, and I think we came up with a richer looking factory as a result of touring those facilities.”

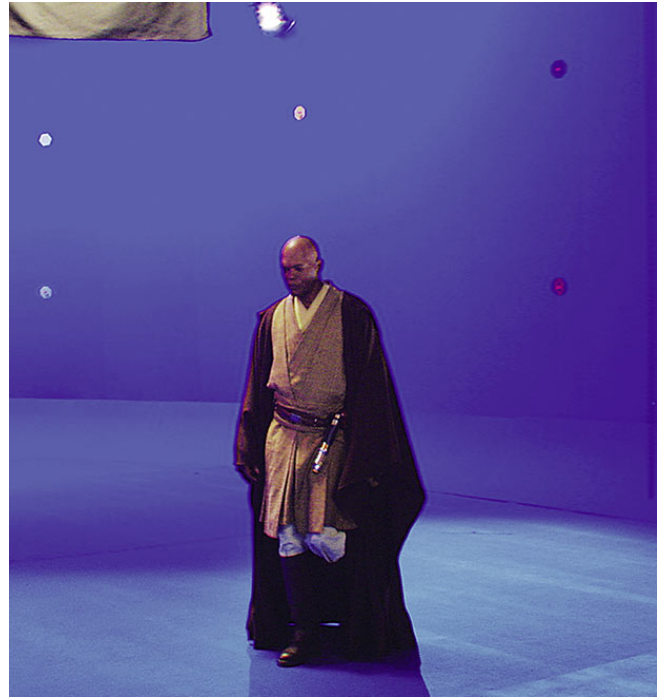


John Knoll on the bluescreen stage. In addition to supervising some of the film’s major sequences at ILM, Knoll accompanied the production during principal photography to address visual effects concerns on the set.

Before jumping into production on the complex, ten-minute sequence, Snow and his team first defined various areas of the factory; then, working backwards from the already-designed super battle droid, they determined what kind of machinery would be necessary to construct each of its parts. “To figure out how one might really build a super battle droid,” said Snow, “we took apart the CG droid model and hypothesized how each part might be made. Then we worked out each step of building a battle droid on the assembly line, drawing it up on a big foamcore board: the stamping out of an ingot, the welding, the molding, et cetera. It goes by so fast in the film, I’m not sure the audience will follow it; but it was very helpful to us in understanding what was happening at each point on the assembly line and in each area of the factory.”

Live-action for the sequence was captured on a bluescreened treadmill in London, with Hayden Christensen and Natalie Portman ducking and dodging blue panels hung from above, which stood in for the CG machines. The action of the assembly line machines had to be worked around those bluescreen elements, especially since few digital doubles would be used in the scene. “There are some digital doubles,” said Hal Hickel, who supervised the animation for the sequence, “but only for stunts that were always intended to be digital doubles, such as Anakin doing a flip up onto a higher conveyor belt. We had to work most of our droid factory animation around what we got from the bluescreen stage.”

The droid factory itself was a combination of a CG foreground set and a miniature background. “Our thinking was that the miniature would anchor the CG set pieces,” said Snow. “Marty Rosenberg was going to shoot the model, and we felt he would bring something to the lighting of it that would help us when it came time to light the CG areas of the factory.” The modelshop crew, led by Charlie Bailey, built a twenty-by-forty-foot factory wall section, while a second team led by John Goodson built four towers in two halves, which could be mixed and



Because many of the movie’s settings were either miniature or computer generated, or both, actors often worked in an entirely bluescreen environment. Footage of actor Samuel L. Jackson on an empty bluescreen stage would later be incorporated into a shot of his character, Mace Windu, walking the computer generated halls of the Senate building. Other characters in the scene were separate bluescreen elements, photographed at ILM. Twilight city views in the background windows were digital matte paintings.



Because many of the movie’s settings were either miniature or computer generated, or both, actors often worked in an entirely bluescreen environment. Footage of actor Samuel L. Jackson on an empty bluescreen stage would later be incorporated into a shot of his character, Mace Windu, walking the computer generated halls of the Senate building. Other characters in the scene were separate bluescreen elements, photographed at ILM.

matched. “That, plus some conveyor pieces, comprised our practical tool kit for the factory.”

Twilight city views in the background windows were digital matte paintings.

In addition to practical model pieces, the droid factory featured foreground CG towers and machines. “Everything in the foreground that the characters are interacting with,” said Snow, “moving and not moving, was CG. It was challenging, because we were essentially creating almost the entire foreground factory environment through CG.”

The hard-surface modeling crew built approximately fifty CG factory models within a six-week period. Bruce Holcomb designed and modeled conveyor belts, and Giovanni Nakpil modeled factory towers, working from Ranch artwork. “All of the stampers, the conveyor arms, the foreground conveyors, nearly every factory piece was a computer model built by us,” observed Russell Paul, whose group also fashioned three different types of battle droids seen within the factory: the battle droid from Episode I – colored slightly differently to reflect the reddish Geonosis soil – the new super battle droid with built-in weapons, and the destroyer battle droid. Sequence supervisor Michael DiComo’s layout team employed a tool kit built in Maya to assemble the CG factory pieces into a believable environment.

CG factory geometries were painted and textured by the viewpaint team, which based its work on the textures seen within the real-life automobile factory and foundry. “Viewpainter Ron Woodall and lead look development TD John Walker developed materials for the first couple of factory models,” Snow recalled, “and really established the grimy, industrial feel we wanted.”



*Galactic delegates assemble in the vast Senate chamber to vote on an emergency measure that will broaden Chancellor Palpatine’s powers and extend his term of office indefinitely. Live set pieces had included only Palpatine’s central lectern and a single pod, both elevated from the stage floor and surrounded by blue. The remainder of the Senate chamber was a digital construct, originally built for *The Phantom Menace*. To fill the chamber with hundreds of delegates, digital artists mapped photographs of costumed ILM staff members onto small 2D cards. Greenscreen elements shot for the Episode I Senate sequence and new bluescreen characters were also employed to populate the chamber.*

Hal Hickel referenced videotapes that had been shot at the local factories when supervising the animation of the CG machines. “We had to walk a fine line between the machines moving fast enough to seem lethal and yet still have a sense of real weight,” Hickel said. “We had chompers, which were blades; we had stampers, which were heavy bars that came down and stamped the metal plates; and we had smelters, which hung from the top and irised open to release hot metal into the vats below.

There were also drills, welders, riveters and torches. All of those things had to look mechanized, with hard stops and starts, and a kind of shudder as they came to a stop. We tried to emulate the ease-in and ease-out of the machinery we saw at the factories we visited, and the way the little hoses bounced and shook.”

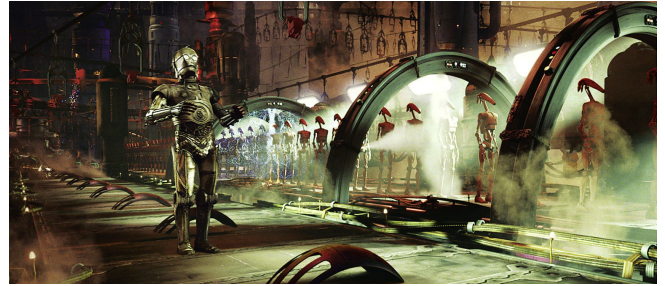
Lighting of the factory was an amalgam of the suggested lighting in the Ranch artwork and what the effects team had observed in the real manufacturing plants. Sequence supervisor Jeremy Goldman and lead technical director Ian Christie established the overall look of the factory lighting

and set up the parameters for the technical directors. Rather than light the areas immediately around the actors as they saw fit, the TDs were tied to the lighting in the bluescreen elements. Generic strobe lighting had been flashed on the actors as they performed atop the bluescreen conveyor, and that random lighting had to be accounted for in the final shots. “One of the more difficult things for us on this sequence,” noted CG supervisor Kevin Barnhill, “was that we had to tailor our interactive lighting to match the lighting in the bluescreen – all the strobe lights and other interactive lighting – which limited what we could do. We also had to deal with some bluescreens that were a little overexposed, due, I think, to the very white suit being worn by Padmé.”

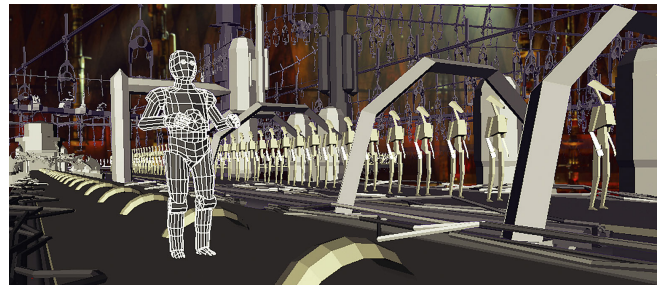
Specific areas of the factory were treated with colored light to help the audience keep track of where each of the characters was located throughout the sequence. “We thought that if the different areas clearly looked different,” said Snow, “it would help the audience follow what was going on. There was a greenish fluorescent light in the area where 3PO was; the foundry where Padmé wound up was lit with warm reds; and Anakin’s area on the welding line had sparks going everywhere.”

Such sparks, steam and other pyro elements, shot on stage at ILM, were added throughout the sequence. While 2D and 3D smoke were also added to some of the shots, the practical elements provided much of the factory’s ambience. “We felt we could do all of that stuff more efficiently with practical elements,” said compositing supervisor Marshall Krasser, “just because of the amount of simulation time that would have been needed to do those elements as CG. I had compositing leads Pat Brennan and Mike Conte develop a technique to populate the environments with these practical steam and spark and pyro elements. The steam was shot high-speed, so that it would move slowly and create a sense of scale in the final shots.”

Toward the climax of the sequence, Padmé finds herself trapped within a hanging cauldron that moves down the assembly line toward a smelter, which releases molten metal into empty cauldrons as they pass underneath. On stage, Natalie Portman was shot inside a full-scale cauldron interior, and that footage was retained for closeups. All other shots featured CG cauldrons, created under sequence supervisor Ed Kramer, which were



Coming to Obi-Wan’s rescue, Padmé and Anakin – followed by R2-D2 and C-3PO – find themselves within the bowels of a droid manufacturing plant on Geonosis. To design the factory, Ben Snow’s team studied the CG battle droid, reverse-engineered how it might be built, then devised an assembly line of manufacturing machinery. Because R2-D2 and C-3PO would perform actions that could not be obtained with a mechanical unit or a suit, both droids were computer generated for much of the sequence, as were foreground and midground factory geometries. Backgrounds were realized through practical models to ground the predominantly CG sequence in reality.



Coming to Obi-Wan’s rescue, Padmé and Anakin – followed by R2-D2 and C-3PO – find themselves within the bowels of a droid manufacturing plant on Geonosis. To design the factory, Ben Snow’s team studied the CG battle droid, reverse-engineered how it might be built, then devised an assembly line of manufacturing machinery. Because R2-D2 and C-3PO would perform actions that could not be obtained with a mechanical unit or a suit, both droids were computer generated for much of the sequence, as were foreground and midground factory geometries. Backgrounds were realized through practical

matched to a miniature foundry set piece shot on stage by Ray Gilberti.

models to ground the predominantly CG sequence in reality.

Padmé's cauldron is just inches from the smelter when R2-D2 and C-3PO arrive on the scene. Bluescreen elements of the two droids had been shot for the factory sequence; but for difficult actions that could not be achieved with the physical characters, the computer generated R2 and 3PO were used. The CG R2 exposes rockets that enable him to fly across a chasm and come to Padmé's rescue. "I had a sketch that Doug Chiang had done in 1996," Billy Brooks said, "which showed R2 with these rockets sticking out of his legs. They had planned on using these rockets on the last movie, but they never got around to it. So they gave me that one sketch, and said, 'We need this.' I designed a mechanism and figured out how the rockets could fold out from that space. Then I did a little animation of that, and showed it to George – and he loved it." The rockets unfold out of R2's limbs in an extremely close shot. "The camera is right in there, so I had to really tweak the textures and make sure they held up. When George saw that shot in nightlies, he asked what part of it was CG – and it was *all* CG. That was a great moment for me."

While R2-D2 rescues Padmé, C-3PO becomes a victim of the assembly line. His head is detached and placed on a battle droid body, while a battle droid head is welded onto his own neck. Although bluescreen elements of 3PO provided frames leading up to the droid's fall onto the assembly line, the fall itself and the following action picked up with the CG version, animated both by hand and through motion capture. "3PO is very difficult to animate," noted Hal Hickel, "because we have to match Tony Daniels in the suit, and everyone knows exactly what that performance looks like. Also, the suit itself limits what you can do in the animation. But because of what George wanted him to do in this sequence – falling on the conveyor belt and flipping over, which the real suit could never do – we had to extend beyond those limitations, while not being too obvious about it. It had to look right, even though we were doing things the real robot couldn't do.

"The shoulders in the suit, for instance, are very restricted in how much they will swivel; but we had to cheat that so that he could hang from his hands in the scene. Fortunately, as we learned about Yoda, audiences imagine that 3PO moves more than he does, so we could cheat it as far as their imaginations filled in. As long as we stayed within the boundaries of what the audience *thought* 3PO could do, we were fine."

Padmé and Anakin are apprehended within the factory and taken to an execution arena, where Obi-Wan is already chained to a central pillar. The execution arena sequence, on the Knoll unit slate, starts with Anakin, Obi-Wan and Padmé fighting off a trio of formidable beasts. Lucas had shot bluescreen elements of the actors, but everything else in the sequence – the arena, cheering spectators in the stands, and the three arena monsters – was created in postproduction.

The arena itself was a miniature, built under lead Michael Lynch. "We built the whole arena in 1/35 scale," observed Brian Gernand, "which turned out to be about ten feet tall and fifteen feet in diameter. We also built a couple of sections in 1/8-scale – Dooku's box and a grandstand area – because they were going to be close to camera in some of the shots. Both the 1/8-scale sections and the 1/35-scale arena were carved out of urethane foam, sculpted to look like stone. We made up a foot-and-a-half-long, foot-wide maquette first, and cut it into eight sections, then built eight sections of the arena based on those pieces. It had to be modular because of its size, and also

because there were going to be three miniature photography units shooting it, due to the large number of shots in the arena sequence.”

Pat Sweeney, Carl Miller and Pete Kozachik headed up the three arena shooting units. “I looked at all the bluescreen footage and figured out the camera position for each shot,” recalled Sweeney. “John Knoll had gone through the whole scene with Rob Coleman, determining where he wanted different actions to take place and where the characters would go; then I took that information and blocked out the cameras accordingly.

“We did the wide shots of the arena first. Then I took half the model and did the shots that would involve just that one side while Pete was shooting the other half; and then Carl was shooting my half of the set in the night shift. As time went on, we just kept trading pieces, going around the whole arena, one piece at a time. It was a very efficient way to do it.”

Unable to stop down the HD camera, Sweeney shot the arena model under very bright lights in order to get an appropriate depth of field. “I almost burned the camera up, I had it so hot,” Sweeney recalled. “I had PAR lights and 20Ks burning on the set, trying to get the stop that I needed. All of a sudden we started getting these weird wavy lines through the image. We felt the camera, and it was so hot! So we had to turn everything off for fifteen minutes and put some fans on it. After that incident, we always had fans to cool the camera; and, of course, we always flagged off the camera to keep the light from directly hitting it.”

Geonosian picadors riding orrrays lead three giant beasts into the arena: the furry, cat-like nexu, the six-legged, crab-like acklay, and the bull or rhino-like reek. The arena creatures had been designed and sculpted into maquette form by the Ranch art department. The designs were then modeled in the computer and textured by the viewpaint crew.

The most highly detailed of the arena monsters was the reek, which is seen in closeup in an encounter with Anakin, who does a flip from the pillar on which he is chained, landing on the creature’s back. The athletic stunt was accomplished with the Anakin digital double. “It was a perfect example of a stunt that couldn’t have been shot in the same way without a digital double,” said John Knoll. “If we’d done that with stunt performers, we would have had to break it up into at least three cuts: a jump shot, a flight shot and a landing shot.”

A blue-covered reek form had been mounted to Dave Young’s gimbal on stage in Sydney as a means of capturing live-action elements of Hayden Christensen being thrashed around, as if atop the animal. The animators then had to match the movements of the reek to that live-action. Rob Coleman and John Knoll had conferred with Young on the set, making sure the gimbal setup could simulate the appropriate moves. “They described the movement to us,” said Young, “and showed us tapes of various animals to use as reference. For the reek, they showed us tapes of a rhinoceros, and



Captured by Geonosians and the henchmen of Count Dooku – a renegade ex-Jedi heading the secessionist movement – Obi-Wan, Padmé and Anakin are chained to pillars within a huge execution arena, where they fight for their lives against three monstrous beasts. Bluescreen plates of the actors attached to practical pillars or riding gimbaled, blue-covered animal forms were the only live-action elements within the arena. The structure itself was a miniature, while the Geonosians were all computer generated. Geonosian designs were based on termites and wasps, also referenced for the animation of the characters.

we tried to duplicate that movement. We could pretty much give them any motion they wanted with this gimbal.”

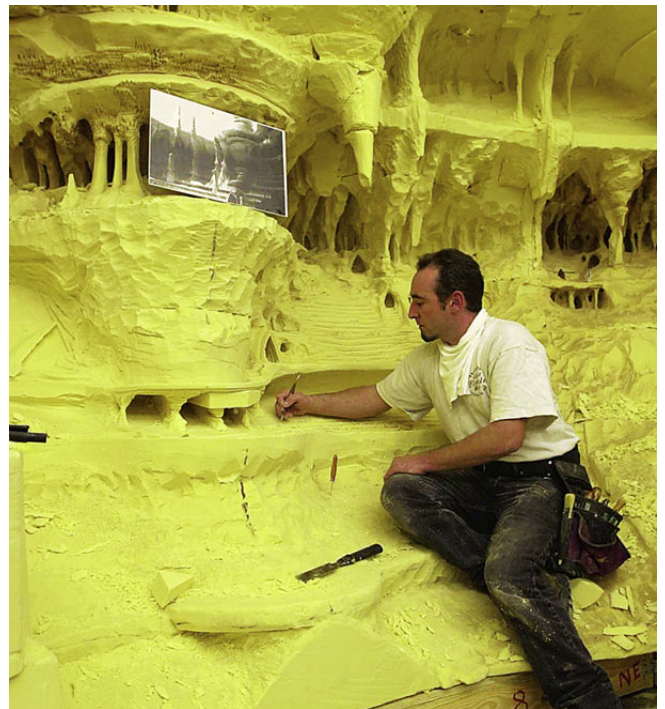
While bulls and rhinos provided movement reference for the reek, and big cats such as lions were the behavioral basis for the nexu, the fantastical acklay – part crab, part alligator – had no real-world counterpart on which the animators could base their performance. “The acklay was the most difficult because it was made up of parts of different creatures,” stated Rob Coleman. “Whenever the designers take the characteristics of one animal and apply them to another to create a whole new animal, there are problems animating that creature. A horse doesn’t have pig’s legs for a reason; and when you try to put pig’s legs on a horse, the body of the horse doesn’t move right.” Animators eventually devised a skittery, crab-like sideways movement for the acklay.

All three arena monsters benefited from a new flesh simulation in development at ILM since the company’s work on the Imhotep character in *The Mummy*. For Episode II, ILM streamlined the pipeline and refined the simulation’s muscle-flexing capabilities. “Muscles have two things happening,” lead animator Dennis Turner explained, “how much they jiggle, and whether or not they are flexed. With the flesh simulation, both of those things could be driven procedurally, using flex curves. Half a dozen curves could drive several dozen muscles. To hand-animate every muscle and every little jiggle would have been a prohibitive amount of work. But with this, we built in the parameters of each muscle’s amount of jiggle, and built in the actual shape of the muscle and how much flex we wanted.”

Wide shots of the arena battle featured not only live-action elements of the actors shot on the minimal set in Sydney, the arena miniature, the CG creatures and digital doubles, but also thousands of cheering Geonosians in the stands. The pod race in Episode I had also featured a stadium filled with spectators; but that environment had been even and symmetrical, unlike the Geonosis arena, which had more organic shapes and was made to look as if it had been carved out of stone. “On the last



The arena miniature – ten feet tall and fifteen feet in diameter – was built and photographed in eight separate sections, enabling multiple model units to shoot simultaneously. The climactic action sequence was so long and complex, it took a full month of shooting, both day and night, to capture all the necessary arena camera angles and elements.



The arena miniature was an organic sculpture, designed to look as if it had been carved out of native rock. Modelmaker Jon-Paul Guidinger at work on the miniature.

picture,” noted John Knoll, “the stands were in very regular lines, like a grid, and so it was pretty easy to create a procedural tool to distribute characters along those lines. The stands in *this* arena were like freeform sculpture – no two bleachers were parallel to each other. So we had to make a CG representation of the bleacher boundaries to put all the CG creatures on those surfaces. We got a scan of the interior of the stadium miniature, and then our modelers used those surfaces to create splines that represented the bleachers for us to distribute creatures on.”

The Geonosians in the stands were created through ILM’s improved crowd simulation tools, which picked from more than a hundred animated motion cycles, and applied them to the characters in a procedural fashion, using a system devised by sequence supervisors Indira Guerrieri and Pat Conran and lead TD Khatsho Orfali. The crowd simulation’s ‘mixer’ determined how those cycles were delegated to characters within a given shot. “We had what we called a ‘group map,’ which was applied to the environment,” explained Henry Preston, “and it dictated that the group in that part of the environment would behave in one way, while a group in another part of the environment would behave differently. Sliders controlled the transition from one animation cycle to another – they could control the transition from flight to landing, for example.”

Sliders also controlled the excitement level of the spectators. “We wanted the ability to excite the crowd at appropriate moments in the arena sequence,” Knoll. observed. “For instance, if one of the arena monsters stabbed at one of our heroes, we wanted to see a reaction to that in the crowd. We could animate excitement levels with sliders – high, medium, low. A percentage of the creatures had wings, so there was some fluttering wing animation as part of that, as well as arm waving and fists-in-the-air animation.”

Additional controls were developed for later in the sequence, when 200 Jedi knights arrive at the arena and spectators begin fleeing the stands. “There were walkways and staircases and exits in the arena,” explained Knoll, “and so when the creatures panic and start to leave, we needed tools that would enable them to make semi-intelligent decisions about where they were going, what they had to walk around, et cetera. So we worked that all out, with some of the characters fleeing in one direction, and some fleeing in another. There were some pretty clever tools that generated reasonably autonomous behavior by setting up paths, and setting up percentages of how many should go on each path. Decider boxes were part of the CG representation, and as the characters reached a decider box, it would randomly determine whether this particular character would go up a staircase or keep walking down a walkway or whatever. The decider boxes were a way of generating more organic behavior.”

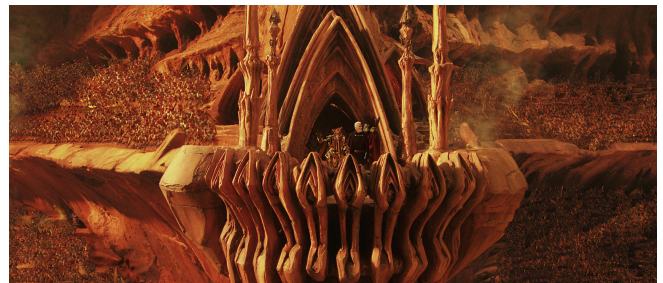


In addition to the eight 1/35-scale arena sections – carved out of dense urethane foam – the modelshop built a separate, 1/8-scale model of Dooku’s viewing box and adjacent grandstands to accommodate a number of closeup views required in the sequence. Modelmakers Carol Bauman and Mark Siegel at work on the enlarged miniature section. Bluescreen elements of Dooku and his Trade Federation cohorts, shot by the main unit, were composited into the model photography.

With the arrival of the Jedi warriors, a battle between them, the Geonosians and the battle droids erupts in the arena. Nearly 100 students from Sydney martial arts and Kendo schools had been shot second unit to provide elements of fighting Jedi, while the crowd simulation supplied the battle droid and Geonosian masses. Motion cycles for the battle droids were motion captured, with James Tooley performing on the motion capture stage, as he had done for Episode I. Tooley's technical animation group executed more than a hundred rigid body simulations for shots of battle droids being sliced and diced by lightsabers. "We had six or seven prescored battle droid models that we could substitute in at any given time," observed Tooley. "Then we'd run the rigid body simulation and that would break the droid apart. It was the same simulation used for exploding ships."

With many of their number dead or wounded, the surviving Jedi are surrounded by Geonosians and battle droids, all poised to fire at Dooku's command. But, suddenly, hundreds of clone troopers in Republic ships pour into the arena, and a much larger-scale conflict breaks out. A typical arena battle shot featured the miniature arena in the background, a CG ground plane, live bluescreen Jedi wielding lightsabers and deflecting laser fire, CG droids, clones and ships, CG Geonosians and both practical and CG pyrotechnic elements. "We added practical smoke columns throughout," said Knoll unit compositing supervisor Dorne Huebler, "just to give the arena miniature a sense of scale. The composites for these shots had everything but the kitchen sink to create the atmosphere of chaos and mayhem George wanted. Compositing leads Tami Carter, Pat Tubach, Sean Mackenzie and Jay Cooper made major contributions to help meet the challenge." More smoke columns were added to later sequences to suggest the progression of the conflict, also indicated in the virtual ground plane, which was textured to show more damage as the battle continued.

The Muren/Snow unit picked up the action as the battle spreads outside the walls of the arena and onto the surrounding terrain. The epic scope of the 180-shot clone war sequence required expansive environments – miles and miles of terrain for aerial shots of ships flying overhead, as well as a plane on which the ground battle would take place. "We thought that for shots down on the ground with the clones and the droids, it would be good to have an actual miniature ground plane," remarked Ben Snow. "So the modelshop built a fairly large, forty-by-sixty-foot ground plane miniature, using the photographic material from the southwest as reference. They used ground walnut shells for scaled-down sand, as well as some special-ordered fine sand from Arizona, and sculpted rocks out of urethane foam. This ground plane was a big tool kit that we could move around to shoot any number of different ground-level shots." The miniature terrain was assembled in forced perspective – 1/8 scale at one end and 1/48 scale at the other.

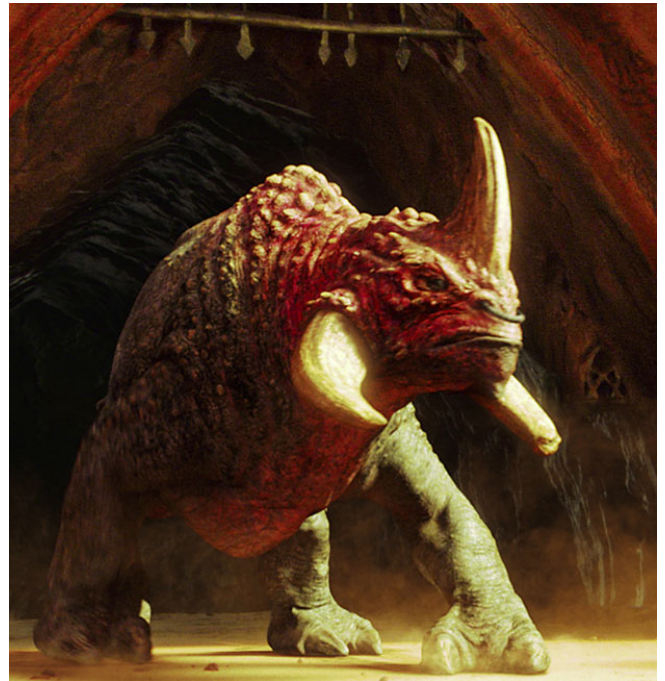


Dooku oversees the spectacle from his viewing box. In addition to the bluescreen element of actor Christopher Lee as Dooku, the shot featured a computer generated Poggle the Lesser – the Geonosis leader – and thousands of Geonosian spectators, created through ILM's crowd simulation program. The program picked from a hundred hand-animated motion cycles and applied them to the Geonosian mob procedurally. Sliders controlled the excitement level of the crowd.

While that miniature served for foregrounds, midgrounds were computer generated terrain and backgrounds were assembled from the photographic stills, stitched together into 120 panoramas by

Katie Morris' roto crew. Compositing lead Leah Anton handled the initial setup in the composites. For shots featuring large or elaborate camera moves, requiring some perspective shift, the stills were mapped onto a digital cyclorama. In addition, digital matte artist Caroleen 'Jett' Green painted a yellowish sky, which was projected onto a CG sphere and utilized throughout the sequence. Hayden Landis supervised the creation of shading and rendering techniques to tie all these elements into the final camera moves and action.

To choreograph the battle itself, Muren, Snow and their teams relied on Ranch animatics and war reference footage, both real and cinematic. "I had just come off *Pearl Harbor*," Snow recalled, "so I'd seen a lot of war reference by then. When I first talked to George about the clone war, I had assumed that he wanted something like a nineteenth century battle – a Napoleonic conflict, or something out of the Civil War, with two forces blasting away at each other with all this new technology. And, like the Civil War, casualties would be enormous because nobody really knows what they're doing with the new technology. So we had started choreographing the clone war that way." Integral to that conflict style was the almost bird-like flocking behavior of the battle droids, as established in Episode I. "The droids are more sophisticated this time – they're a bit faster, and they have much more firepower – but they still walk straight into enemy fire."



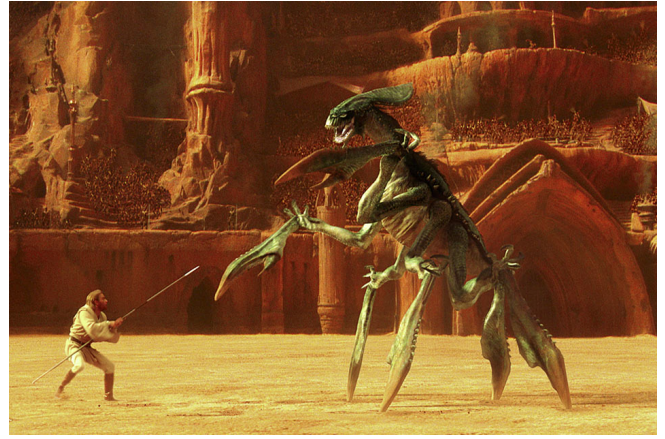
One of the arena beasts – a reek – is released into the stadium. Since the sequence would feature numerous closeups of the creature, detailed viewpaint textures were mandated, accomplished through a new volumetric paint program. A shot of Obi-Wan fighting an acklay was an homage to a Ray Harryhausen stop-motion scene from *Mysterious Island*, in which that film's lead characters battle a giant crab. After some trial and error, the animators developed a skittery, sideways movement for the insect-like acklay.

In contrast to the dim-witted, if big-stick-carrying droids were the intelligent clone troopers. “George said that the clones were clever,” Snow remarked. “He said: ‘They’re human, they know a thing or two. Unlike the battle droids, which are machines that just march mindlessly into gunfire, the clone troopers are like trained Vietnam fighters, with squads of guys moving around.’ So there was a dichotomy there – this clash of the droids, who just march to their doom like Napoleonic soldiers, versus these smarter clones moving in squads. And that changed the way we choreographed the clone war battle. We ended up with whole battalions of droids coming in one direction, and squads of clones moving all over the place.”

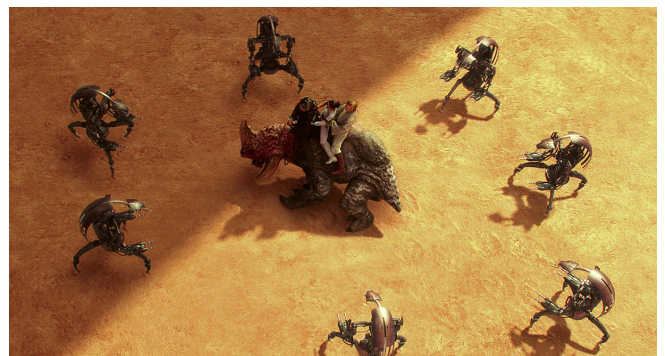
Ships featured in the clone war included Neimoidian core ships, which take off near the end of the conflict, Republic transports, and the helicopter-like attack gunships. Ground hardware included not only various configurations of droids, but also large-scale tanks and transports, such as the crawlers, reminiscent of the walkers in *The Empire Strikes Back*. One of the responsibilities of ILM’s art department was to translate the Ranch concept artists’ beautiful but sometimes vague renderings of these ships and machines into more specific designs. “On the painting of the crawlers we got from the Ranch, for example,” said Alex Jaeger, “the legs on the crawlers were just little paint strokes. And there were very few practical models made for the ships since they were all going to be CG anyway. So we had to break those designs down and detail them. Then we would run our more detailed versions by the Ranch artists to make sure that what we came up with was in line with what they were thinking when they did their paintings.”

Due to long-running and close-to-camera shots, some of the ships, most particularly the gunship, required a very high level of detail. “On stage in Sydney,” Russell Paul said, “production had built a small section of the gunship; but when they did the reshoots in London, they didn’t have any set piece for the ship – it was just blue. So the CG attack gunship had to fill in for every shot. It had to hold up for long shots where Anakin and Obi-Wan are in the opening of the ship, talking.”

Most of that detailing fell to Steve Walton of the viewpaint team. “The gunship was one of the most challenging hard-surface models we have ever done,” admitted Jean Bolte, “because of the length of time it was on the screen, the closeness of the camera, and the fact that it is seen from every angle. It isn’t just flying past you – you are inside that thing and under it and standing next to it.” A recently



*One of the arena beasts – a reek – is released into the stadium. Since the sequence would feature numerous closeups of the creature, detailed viewpaint textures were mandated, accomplished through a new volumetric paint program. A shot of Obi-Wan fighting an acklay was an homage to a Ray Harryhausen stop-motion scene from *Mysterious Island*, in which that film’s lead characters battle a giant crab. After some trial and error, the animators developed a skittery, sideways movement for the insect-like acklay.*



developed volumetric paint program was crucial to creating that level of detail. “The volumetric paint program could be almost infinitely up-rezed. We could keep zooming in, closer and closer. As long as we kept zooming in on the model, we could keep adding resolution to it.”

Hal Hickel’s group executed hero animation for the chaotic clone war, with different leads heading up the animation of clone troopers, battle droids, ground machines and ships. Throughout, the animation team was guided by intricate 3D animatics provided by the Ranch. “Those animatics were great,” observed Hickel. “They really nailed shots early on that remained virtually unchanged all the way to the end. We were able to take their Maya files and use their virtual camera moves directly. Paul Kavanagh, who was in charge of the animation camera work, converted the animatics files into our world space and created matchmoves using their cameras. We didn’t use any of their geometry – the ground planes or the machines – but we used their cameras, because they were good guidelines for framing and speed.”

Hero foreground and midground animation was augmented with background characters provided by the choreography team, led by Daryl Munton. “Creating a sense of epic scope in the clone war was very important,” said Ben Snow. “We’ve been hearing about this clone war for years, ever since the first movie; so it had to be very big, and very *Star Wars*-sized. To get that size in these big battle scenes, Daryl’s team would lay out great numbers of background characters, combining procedural techniques with hand-animated and motion captured character actions.”

To add to the general chaos, Snow’s unit shot practical pyro elements to simulate weapon hits. In both the practical and computer generated hits, the unit strove for variety so that each weapon would look as if it fired its own distinct emission. “In the crawlers, for example,” said CG supervisor Curt Miyashiro, “the main gun fired what looked like a hot core ball, with a trailing element, and a unique, three-star explosion. To differentiate the technology between missile droids and attack gunships, we had a white plume with a blue exhaust coming out of the attack gunships, whereas missile droids emitted a black, dirty contrail, with magenta sparkles coming from the head of the exhaust plume. A number of our TDs developed the smoke trails, using particles.”

In an early clone war shot, Mace Windu and Yoda direct the battle from a control center as a gunship is downed by laser fire. A practical set piece provided the control center, including seats and a donut-shaped console. The explosion of the gunship was accomplished by lead animator Scott Benza running the force simulation on a break-apart CG model. Ben Snow did a special pyro shoot with a blue-painted mannequin of the gunship to capture additional explosion elements, composited by the Sabre unit. Also featured in the shot was a bluescreen element

After surviving their separate encounters with the arena beasts, Anakin, Padmé and Obi-Wan, astride the reek, are surrounded by super battle droids ready to fire at Dooku’s command. During principal photography in Sydney, the three actors were shot on a blue-covered, roughly-reek-shaped form, mounted to a gimbal that simulated the creature’s planned movement. That bluescreen photography was then composited with CG battle droids, CG reek and a CG arena ground plane.



Two hundred Jedi enter the fray within the arena, fighting battle droids and Geonosian troops. In addition to hero Jedi characters, such as Mace Windu, the fight sequence featured generic Jedi combatants portrayed by nearly a hundred martial arts and Kendo students cast from Sydney schools and trained by stunt coordinator Nick

of Mace Windu, and the painted sky, combined by compositor Todd Vaziri.

In one of the earliest clone war shots to be finalized, large spider droids appear on the battleground, moving straight toward camera. The spider droid, painted by Steve Bell, was modeled to look like a giant ball with multiple legs. Technical director Raul Essig executed the shot, which, as one of the first to go into production, became the hero shot for developing the overall look of the clone war. “That shot had all the things we ended up doing for the clone war,” noted Curt Miyashiro, “the panorama in the background, the all-CG midground and foreground miniature, all blended together.”

Another pivotal shot features Mace Windu, Kit Fisto and Ki-Adi-Mundi conferring with a clone commander in an assembly area. Hal Hickel’s team animated foreground clones, while background clones were produced by the choreography team. “That shot was very close on the CG clones,” remarked Miyashiro, “so they had to look as photoreal as possible. The level of detail in the viewpoint was really important, as was the lighting. We also had shaders to make the clone troopers appear more scuffed up and dirty as the battle progressed.” In addition to the CG clones, the final shot included bluescreen elements of the live-action characters, a miniature ground plane, CG terrain in the background, CG ships and 2D atmospherics.

In one of the sequence’s signature shots, executed by TD Gonzalo Garramuno, the ground-level camera pans with a group of clones, revealing crawlers in the immediate foreground and a tank transport ship in the midground, which lands, drops off a crawler, and takes off again. “It is a huge shot, with an epic feel,” commented Miyashiro. “You can see a cast of thousands in the background, walking over the sand dunes. R.D. Wegener had the challenge of this shot, compositing all the 2D and 3D elements together – there were dozens of elements and thousands of characters.”

During a chase in the latter part of the battle, the characters fly into an area of sand dunes. After the shot had been finalized, Lucas decided to alter the color of the sand dunes on the ground plane miniature to more effectively tie them into the other Geonosis landscapes. In compositing, Marshall Krasser recolored the light pink sand on the miniature to a dark red sand with golden highlights.

Recoloring of the sand was also necessary for a shot in which the gunship carrying Padmé, Anakin and Obi-Wan is hit by weapons fire, causing Padmé to fall out and roll down a sand dune below. For the live-action portion, Natalie Portman’s stunt double had been filmed rolling down a mound of sand on location. A sand dune miniature was then shot in two motion control passes – one in which the sand was smooth, and another in which divots had been made in the sand, as if from the consecutive impacts of her rolling body. Portman’s stunt double was then rotoscoped out of the original plate and locked into the miniature plate. “As she rolls down,” Krasser explained, “compositor Sandy Karpman did a soft-split wipe between the motion control pass of the miniature with the smooth sand and the one with the divots.”

Dooku and his co-conspirators oversee the battle from a subterranean war room. The only thing production had shot for the scene were bluescreen elements of Christopher Lee and the two

Gillard. Motion capture provided gross animation for the computer-generated battle droids. Digitally prescored versions were created for shots of droids being sliced apart by Jedi lightsabers. A clustered CG-3PO – his head attached to a battle droid body on the droid assembly line – finds himself marching into the arena to fight the Jedi who are attempting to rescue his creator and friends. A CGC-3PO head was employed for the sequence, animated to replicate Anthony Daniels’ highly recognizable performance in the suit. Though the battle droid did not deviate significantly from the look established in *The Phantom Menace*, its coloration was altered to reflect the reddish Geonosian soil from which its origin metals were presumably mined.

Neimoidians, Nute Gunray and Lott Dod. With no time left to construct a detailed miniature, ILM created the environment through a combination of matte painting and projection-mapping techniques. Modeler John Goodson built a rough, four-foot-diameter physical model of the war room, then Paul Huston photographed it and brought that photography into the computer for painting and detailing. “I photographed the model from all different camera angles, and those became the backgrounds for the entire scene,” said Huston. “There were also animated elements added – little lights and screens and holographic elements – which really brought it to life.” The monitors displaying graphics and holographic images were generated by Phil Metschan of the ILM art department.

Witnessing the escalation of the conflict from the war room, Dooku and his co-conspirators attempt to escape the planet – Dooku in his Interstellar Sail Ship, the Neimoidians in their vessel, introduced in Episode I. A shot of the Neimoidians entering their ship featured the only physical ship model used in *Attack of the Clones*. “We already had that Neimoidian ship model from the last show,” explained Pablo Helman, “but the original build was only the lower bottom and back end of the ship; so we had to build a CG model that could be animated to show the full ship leaving the dock.” The Neimoidian performers were shot walking up a bluescreen ramp, and that footage was combined with the model photography. A 600-frame push-in on the ship as it takes off was accomplished with 2D photographs of the model incorporated into a digital matte painting.

As Dooku makes his way on a speeder to the hangar housing his sail ship, Jedi forces fire upon and down one of the Neimoidian battleship cores. “On the ground,” explained Ben Snow, “the cores have legs, which retract as the cores go off into space and join the donut-shape ships. They take off, and then the Jedi forces fire upon them from a clone tank, with a laser effect – developed by Pat Brennan – ripping into the battleship core as it hits. The clone tank laser-cuts huge holes into the battleship core, setting off secondary explosions, and sending it crashing to the ground.”

Viewpainters painted gouges into the CG core, and also detailed the exposed interior to help sell the one-mile-diameter scale of the ship. The pyrotechnics of the ship’s destruction were created through a combination of particle technology, created by technical director Sam Kao, and 2D practical pyro elements mapped to cards and composited by Mike Conte. Particles also simulated falling debris and dust. “When the Neimoidian core ship crashes to the ground,” said Snow, “it kicks up this huge plume of dust that envelops the characters, a simulation done in Maya. We also used an all-CG volumetric dust that lead TD Will Geiger developed for shots of the troops being enveloped by the dust.” The core ship explosion and crash were among the last shots finalized by ILM for the show.



The conflict extends outside the arena walls when thousands of clone troopers arrive in Republic transports. A forced-perspective ground plane miniature provided foreground landscapes, extended with CG terrain and panoramic backgrounds. The yellow Geonosian sky was a painting projected onto a CG sphere. The miniature and virtual clone war environment was populated not only with classic Star Wars-style hardware – such as Trade Federation core ships and crawlers – but also thousands of CG clone troopers, animated to reflect the characters’ intelligence and battlefield skills.

Obi-Wan and Anakin follow Dooku to the cavernous hangar housing his Interstellar Sail Ship, where they engage the ex-Jedi master in a lightsaber fight. One side of the hangar had been built as a stage set in Sydney, complete with a full-size sail ship, while the other side was created in postproduction, often to accommodate Lucas' reframing of live-action shots. Looking for a wider view of the action, for example, Lucas would shrink a full-frame shot of the hangar interior to half-frame, requiring the visual effects team to fill in the remainder of the frame with a virtual environment. Rather than build an entire set in 3D, however, the digital artists calculated exactly what the camera would see in each of their shots, and created those views in 2D.

"From the blueprint of the real hangar set," Samir Hoon said, "we built a rough 3D model, just to establish the angles that we needed: 'If the camera is here, what are we seeing in the background?' Then we created all of those specific backgrounds with matte paintings by Simon Wicker or by mapping images on cards. We plotted out where we could use existing images or generate additional images from the digimatte department, and used those as backgrounds." The virtual hangar environments were assembled by the Sabre unit.

The powerful and skillful Dooku quickly dispatches Anakin and Obi-Wan and is preparing to kill them when Yoda appears to square off against the rogue ex-Jedi. The prospect of creating a believable lightsaber duel between the six-foot-five-inch Dooku and the frail, diminutive Yoda contributed to many sleepless nights for Rob Coleman. "I remember being worried when I first read about the fight in the script," Coleman allowed. "It took over a year of constantly thinking about it and talking to George about it before I could get my head around the idea of an 800-year-old Yoda engaging in this very physical fight."

"We all fought it a little bit," Pablo Helman agreed, "because it didn't fit with our idea of Yoda as this aged creature who walked with a cane. But then we started to think of it as a situation where he pulls all his strength together for this fight – just like real people do when they have an adrenaline rush. We all eventually bought into that idea."

To ease the audience into the fight and avoid a jarring transition from the frail Yoda to the physically adept Dooku, Lucas, Knoll and Coleman conceived of a series of shots at the start of the battle in which Dooku and Yoda would exchange bolts of energy – a blue lightning-like force emanating from their fingertips, realized as a Maya particle effect. The Sabre unit added glows and interactive light onto the characters and environment to sell the effect.

The exchange turns physical as Dooku and Yoda draw their lightsabers and engage in a long, fierce battle in which Yoda displays extraordinary athleticism and fighting skill. "George has always



Overwhelmed by Republic forces, Dooku and his co-conspirators attempt to escape the planet, the former traveling by speederbike to a cavernous hangar housing his Interstellar Sail Ship. There, Dooku engages first Anakin, then Obi-Wan and, finally, Yoda, in a contest of lightsaber virtuosity. Freed from the physical limitations of the puppet, Lucas was able to create a fighting Yoda who was acrobatic, skilled and powerful. Conceptualizing and executing the fight between the small, frail Yoda and the over-six-foot-tall Dooku had been one of ILM's biggest challenges, but the final result proved to be the movie's most crowd-pleasing moment.

wanted to see Yoda fight, I think,” explained Coleman, “and so he had a sense of how he wanted the fight to look. For Yoda’s movement, he mentioned images like the Tasmanian Devil; and we talked about the fact that Yoda could bounce twenty feet in the air. After getting a general sense of the scene from George, I got together with Tim Harrington, one of my best animators, and said, ‘Okay, Tim, we’re going to figure this out.’ We started moving Yoda very quickly; but as we showed that animation to George, he wanted him to move faster and jump higher. We just kept working on it, with Tim doing most of the shots himself. There was no moment of epiphany, no moment of, ‘Hey, we got it!’ We just gradually got there.”

In addition to the CG Yoda, many shots in the scene featured the digital double for Christopher Lee, who, at 78 years old, was not capable of performing the fight’s more strenuous actions. In some instances, the digital double’s head was tracked to Lee’s stunt double, shot on stage. “They had shot the stuntman in a wig so he would more closely resemble Christopher Lee,” Robert Marinic explained, “but his facial features still didn’t match. So we replaced the stunt man’s head with the CG model of Christopher Lee’s head. The camera comes pretty close to it – in one shot, just before he jumps up and does a flip, it was from about the waist up. We also did a full digital replacement in a couple of Dooku shots.” Heidi Zabit’s rotoscoping group created articulate mattes and painted out the stunt double’s head so that the digital version could be tracked to his headless shoulders.

Unable to disarm Yoda, Dooku escapes in his sail ship, next seen descending into the red skies of Coruscant at sunset – a CG ship flying through 3D matte paintings of the city by Jonathan Harb and Masahiko Tani. “I spent most of my time on these shots modeling,” Harb related. “I made one render for fill, and one ambient occlusion render, combining those two renders and augmenting them with paint. Final paintings were then projected from forty different projection cameras. 3D cards in AfterEffects allowed for fine-tuning the painting without re-rendering elements.” Polyfill clouds photographed with a digital camera and assembled in Photoshop completed the sky.

The sail ship lands in a small hangar, the interior of which was built as a miniature in the final days of production. Exteriors were 3D matte paintings. After a brief meeting between Dooku and Darth Sidious, the movie cuts to the interior of the Jedi temple, where a somber Yoda, Obi-Wan and Mace Windu consider the impact of the impending war. Yusei Uesugi provided the dramatic sunset view outside the temple windows, augmenting a photographic element with matte painting. “I knew, from thirteen years of being a matte painter, that it is impossible to paint a sunset sky like this,” Uesugi said, “and that photographing a real dramatic, beautiful sunset was going to be essential. So for almost half a year, Masahiko Tani and I went outside every evening, looking for that gorgeous sunset to photograph. By the time we had to start working on these shots, we had taken about three hundred pictures; but none of them were very good, and I was starting to get nervous.”

About that time, Uesugi took his vacation, visiting a friend in Tokyo. Coincidentally, his friend had taken a number of digital photographs of a very dramatic sunset. “It was the sky on September 11 that he had photographed,” Uesugi said. “The skies were so dramatic, he had thought to himself that it looked like the end of the world. Then, a few hours later, he found out what was going on in New York. He was kind enough to let us use those digital images for these shots.”

As the clones assemble below, preparing for war, Palpatine, Senator Bail Organa (Jimmy Smits) and other Republic officials watch from a Senate building balcony. Pablo Helman’s unit was given a plate

with only Palpatine and Organa standing on a practical set. “The four guys standing behind Organa were not actually there on the balcony when it was shot,” said Helman. “We shot guys in masks here at ILM, added them in, and also added the view of the transport area, where the clone army is boarding ships. The background was all a matte painting by Yusei Uesugi, with CG clones and ships moving through it.”

The great clone war has begun; but the film ends on a romantic note, with Anakin and Padmé being married secretly at the lake retreat on Naboo, their only witnesses R2-D2 and C-3PO. The droids were bluescreen elements added to a live-action plate of Christensen and Portman filmed at Lake Como.

The delivery date for all 2000 effects shots was April 1, 2002; but that date did not mark the end of ILM’s work on the show. For the first time, the company would produce all the master print negatives in-house, an idea that had originated with director of photography David Tattersall.

“Typically,” explained John Knoll, “we film out every effects shot as a separate entity. Then we ship it off, and, at the lab, a timed interpositive is made that everyone agrees is the master. Multiple master printing negatives are then struck and all of the prints are made from those. So, on a typical project, the effects shot that we film out goes through two optical generations downstream.

“On this show, we were going to film out the whole movie anyway, to go from HD to film; so David thought, ‘If we’re going to film out the whole movie, why not film it out *multiple* times and make the master printing negatives directly?’ We filmed out entire twenty-minute reels as a single unbroken piece of negative, multiple times to make all the printing negatives. And then the lab made their prints from those. It allowed us to save two optical steps. Everything was first generation, which meant the quality of the image was better.”

ILM also maintained control over the film’s color timing. Rather than have the color timing done by an outside lab after the effects shots had been scanned out to film, the color timing was done in the digital realm, *before* scanning out to film. “We’d often had the experience of creating a particular look for a shot,” remarked Knoll, “but then changes would be made in the color timing, and the shot wouldn’t work as well as it had originally. By doing the color timing here, we had more control over the final look.”

With the release of *Attack of the Clones*, George Lucas is only one movie away from completing his *Star Wars* saga, and only three years away from the end of a filmmaking odyssey that will have spanned nearly thirty years. The past twenty-five of those thirty years have yielded the most explosive advances in effects technologies ever seen in the film industry – and that is no coincidence, because many of those advances evolved directly out of Lucas’ determination to get his imagined *Star Wars* universe on film.



In a closing scene, the sun sets on Coruscant as the Republic prepares for war. Digital matte supervisor Yusei Uesugi and matte painter Masahiko Tani scouted the dusk skies for months and took hundreds of digital photographs looking for one that would form the basis for the blazing sunset, but still had not captured a suitably dramatic sky when the closing shots went into production. Photographs captured by a Uesugi friend and colleague in Tokyo – on

"It is all about telling a story," Lucas mused, "but translating that story onto film, physically getting that stuff to be real has always been the challenge.

September 11 – finally provided the long-sought magnificent view.

In that way, filming this second series of *Star Wars* movies is following the same pattern as the first. Doing the original *Star Wars* movie was tense and difficult; and I was constricted in what I could do, because there was a very narrow field to work in, technologically. I hit that ceiling very fast, mainly because film is not really designed for science fiction or fantasy. In terms of the technology, just getting from nothing to Point A on the first *Star Wars* was a giant effort.

"Same thing this time around. There was so much work to do just to get into the digital realm for *The Phantom Menace*. We were doing a lot of things that had never been done before – just as we had done for *Star Wars* – and there was a lot of worry about whether or not it was going to work, just as there was on *Star Wars*.

"But on this film, we had it all working, and I was able to move beyond that initial learning process. This time, I knew what I was doing in the digital realm, and I had a sure command of the medium. That meant that I could focus more on the story itself, and not be bogged down with the weight of the technology and how you get it on screen. It's like driving a car – you just want to drive it, you don't want to think about how it works. *Attack of the Clones* was like a smooth-running car. I didn't have to think about the engine; all I had to do was get the story from Point A to Point B."

Star Wars Episode II: Attack of the Clones photographs copyright © 2002 by Lucasfilm, Ltd. All rights reserved. ILM still photography by David Owen, Alex Ivanov and Sean Casey. Special thanks to Ellen Pasternack, Lynne Hale, Nagisa Yamamoto, Miles Perkins and Lori Petrini.

